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DOWNSTREAM EFFECTS OF LAND TREATMENT AND UPSTREAM FLOODWATER-RETARDING STRUCTURES

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Foreword

To those concerned with how land treatment and upstream floodwater-retarding structures may affect flood flows in downstream areas, this study of the Verdigris River watershed will be of interest. The report gives information on the probable effects of land treatment and upstream structures, considered separately and in combination, on runoff from representative storms of different sizes. Although the economics of the study were not carried out to the extent necessary to establish definite conclusions and recommendations for the Verdigris River watershed, it does indicate that a land-treatment program and a system of upstream reservoirs would substantially reduce flood flows occurring in the downstream areas under present conditions.

Although the study pertains specifically to problems in the Verdigris watershed, it is perhaps even more important for its general interest and value to hydrologists and others interested in the technical aspects of watershed work. The explanations and examples illustrating methodology used and results obtained are in sufficient detail to be easily understood and applied. Various cross checks and comparisons show the comparability of results by alternate methods of computation.

The wealth of data contained in the tables and figures facilitate an understanding and analysis of the methods employed. The data also represent a large amount of compilation and treatment of material which will be essential to any further studies in the Verdigris River watershed.

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Purpose and Scope

This study originated in early 1954 as a result of the desire of the Arkansas-White-Red Basins Inter-Agency Committee to coordinate upstream watershed treatment with downstream projects. The Toronto Reservoir project, on the main stem of the Verdigris River, was one of several projects assigned high construction priority by the Corps of Engineers. The upper Verdigris River watershed, in which the Toronto project and upstream programs were being considered, was selected by the Corps of Engineers and the Department of Agriculture as one of the areas for additional coordination studies; this selection was approved by the Arkansas-White-Red River Basin Inter-Agency Committee at their meeting in Tulsa, Okla., January 29, 1954. At that time, an investigation of a watershed treatment program for the entire Arkansas River watershed above the junction of the Verdigris and Arkansas Rivers had been substantially completed by the Soil Conservation Service and the Toronto Reservoir project was an authorized project.

The SCS investigations followed their customary procedures for flood-prevention surveys. In this procedure, selected sample tributary watersheds were studied in detail to obtain estimates of tributary flood damages, the land treatment and small structures needed, and the benefits expected to result from the program. Data and findings of the detailed studies on the sample watersheds were then extended to similar areas of the total area being studied. None of the sample tributaries, however, were in the area of the Upper Verdigris. It was, therefore, necessary as a first step toward coordinating watershed treatment and the Toronto Reservoir project to have firm "in place" data for the entire area above the reservoir. To develop a detailed program, complete with costs and benefits, would have necessitated an investigation somewhat greater than could have been completed before the ending date of the AWR survey. The objective of the study was therefore limited to a calculation of the probable effect of watershed treatment on several representative floods at the Toronto Dam Site (Coyville stream gage). It was reasoned that if the indicated effects were insignificant, it would not be necessary to go further with hydrologic coordination of the upstream program and the Toronto Reservoir project, but if the indications were significant, it would be necessary for the agencies to study the area further.

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[1] The authors gratefully acknowledge their indebtedness to their many friends and coworkers who have generously contributed to the planning and preparation of this report. To John A. Short and H. C. Dean for their guidance and administration of the study; to Victor Mockus and R. G. Andrews for technical advice and assistance in planning and executing the study; to Vernon Maresch and LeRoy Schulk for the economic analysis; to F. DeWitt Abbott, Arthur P. Nelson, and George Smith for the land use, soils, and infiltration data; to the Oklahoma field survey party, Broadus B. Coffman, Chief, for the field surveys; to the Cartographic units of Lincoln, Nebr., and Fort Worth, Tex., for the reservoir site maps and drafting and reproduction of report figures, respectively; to Chester Speer and Mrs. Maureen Ratigan for the bulk of computations involved in the study; and to others who have provided counsel and assistance at various times during the progress of the study.

The study was limited to the above objective except for some economic studies made of the main stem and major tributaries to see if the program was economically feasible. Every effort was made to use standard and acceptable procedures in the hydrologic and economic studies. The studies were made independently by the Soil Conservation Service, other agencies assisting by furnishing available data.

In accordance with the objective, four floods, representing a range of sizes, were selected from the 13 years of record at the Coyville, Kans., stream gage. The drainage area at this gage is 747 square miles, and the gage is about a mile downstream from the Toronto Dam site. For each of the four flood events, the storm runoff was routed to the Coyville gage under each of the following watershed conditions:

(1) Present conditions (to provide a measure of the adequacy of the flood-routing procedures).

(2) With the program of land treatment, as outlined by local Soil Conservation Service technicians, assumed to be in effect.

(3) With a system of 141 upstream floodwater-retarding structures assumed to be in effect.

(4) With both the land treatment and structures assumed to be in effect.

The results of these 16 routings, together with the findings of the economic studies, should provide sufficient information with which to judge the possible significance of the watershed treatment program in relation to the Toronto Reservoir project and with which to develop the possible additional coordination steps that might be required.

General Procedure

The general steps in the procedure follow but not necessarily in the order in which they were carried out:

(1) The watershed area of 747 square miles was subdivided, following watershed and stream boundaries, into 28 subareas, averaging about 25 square miles in size (fig. 1).

(2) For each of the subareas an inventory was made of present land use, farming practices on cultivated land, and pasture and woodland conditions. Soils information was compiled and the principal hydrologic soil groups were determined for each subarea.

(3) The watershed treatment program was developed. This included the land-treatment phase, consisting of the land use changes, improved farming practices, and conservation measures that would restore and improve the soil-resource base to the minimum point where it could be protected and soil losses controlled; and the structural phase, consisting of 141 waterflow-retardation structures to reduce flood damages. The land-treatment phase was planned in sufficient detail so that the data on hydrologic effects were available for each of the individual subareas. Structures were located "in place" and surveyed in sufficient detail to determine reservoir capacity and volume of fill. The structure sites were selected to avoid inundation of cropland and improvements. Structures were designed to discharge 15 cubic feet per second per square mile (CSM) from the automatic drawdown tube, at maximum head.

(4) Four annual flood events were selected from the 13-year published record (1940-52, table 1) of the stream gage at Coyville, Kans. These were representative of the range of sizes and frequencies. The dates of the four floods, the recorded peak discharge, and the percent chance of occurrence, based on the annual flood-frequency line in figure 2 are as follows:

April 13, 1947--having a peak discharge of 16,600 c. f. s. and about a 70-percent chance of being equaled or exceeded in any year.

June 23, 1943--having a peak discharge of 36,900 c. f. s. and about a 30-percent chance of being equaled or exceeded in any year.

June 1, 1941--having a peak discharge of 51,800 c. f. s. and about a 15-percent chance of being equaled or exceeded in any year.

July 12, 1951--having an estimated peak discharge of 130,000 c. f. s. (the greatest of record) and about a 1-percent chance of being equaled or exceeded in any year.

(The rainfall-runoff relationships for the period of record were tested for possible major changes in watershed conditions. This was done by double-mass plotting of cumulated annual runoff against cumulated annual rainfall (fig. 3). Annual rainfall was measured by the average of representative gages, adjusted by subtraction of a constant based on the differences between annual rainfall and annual runoff. No change in rainfall-runoff relationships that might be due to changes in watershed conditions was apparent. There appears to be a difference in the relationships for wet and dry years, which is to be expected.)

(5) All available rainfall data for the area were studied, and the rain producing, and antecedent to, each of the four selected floods was analyzed. Isohyetal maps, generally for 24-hour periods, were prepared for each of the four floods. After studying these maps, final estimation of the rainfall for each of the four events for each of the subareas was in terms of hourly amounts; these hourly estimates were based on the record at the recording rain gage most representative of the rainfall for the individual subareas and on the

daily record of applicable standard gages. Total amounts of rainfall estimated in this manner agreed closely with the amounts estimated by means of the isohyetal maps.

(6) Total runoff from each of the subareas for each of the four storms was estimated by a method using rainfall-runoff relationships, taking into account the extent of soil groups; land use, cover condition, and farming practices; antecedent moisture conditions; duration of storm and total rainfall; and season in which the flood occurred. Total runoff for the watershed as estimated by these procedures was compared with total direct runoff at the Coyville gage, indicated adjustments of the various factors were made, and the same factor was used thereafter in making estimates of the watershed treatments needed and their effects.

(7) Triangular runoff hydrographs were prepared for each of the four floods for each of the subareas, by use of the watershed and storm characteristics.

(8) The main stem and major tributaries were subdivided into 21 reaches to be used in routing the selected floods. Stream-bed profiles, stream and valley cross sections, and high watermarks for the 1951 flood were obtained for all reaches. Manning's "n" values were estimated for channel and overbank flows at representative points for each reach.

(9) The hydrographs for each of the four floods were routed downstream to the Coyville gage by a modified Goodrich-Wisler[2] flood-routing procedure. This method employs a semigraphical solution to the storage equation in the form:

$$\left(\frac{2S_1}{\Delta t} - q_1\right) + (I_1 + I_2) = \left(\frac{2S_2}{\Delta t} + q_2\right)$$

in which

Δt = routing time interval

S = reach storage

q = outflow from the reach

I = inflow to the reach

For each routing reach, the relationship between discharge and valley storage was determined on the basis of assumed steady flow. This relationship was then used to construct working curves used to solve the storage equation. Based on the triangular runoff hydrographs, each of the four floods was routed to the Coyville gage and the computed or routed hydrograph compared with the observed hydrograph, allowing for base flow. Within the limits of possible error in estimates of the factors affecting the shape of the routed hydrograph, proper adjustments were made in the factors to achieve better correspondence of the routed with the observed hydrographs.

(10) The same general procedures used for estimating total runoff and for constructing hydrographs for each subarea under natural conditions were used to estimate total runoff and to construct triangular hydrographs for each subarea for each of the four floods with (1) the land treatments assumed to be in effect, (2) the system of 141 floodwater-retarding structures assumed to be in effect, and (3) with both the land treatment and structures assumed to be in effect.

(11) The hydrographs for the subareas for the four floods for the three conditions were routed to the Coyville gage by the same procedures as were the hydrographs for natural conditions.

(12) To provide a measure of the feasibility of the program, a detailed study was made of crop and pasture damages on the main stem and major tributaries. Land use and crop distribution in the flood plains of the main stem and major tributaries were completely inventoried for all the reaches (fig. 4). Data on crop yields and costs of production, with and without floods, were systematically collected. From these data, damageable values per acre were computed. A damage factor based on depth of inundation was established and the damage per acre for various depths of inundation computed. From the cross sections and routed discharges, the area inundated to various depths was determined for each of the four watershed conditions. From these data the damage to crops and pasture was computed for each flood of record. This was reduced to an average damage per year for the 13 years. A less detailed estimate was made of other rural damage, based on a field survey and comparison with the crop and pasture damage. Damage data were not collected or damages computed for areas in the flood plain of minor tributaries, for urban areas, or for areas or installations subject to damage by sediment.

Results and Conclusions

The results of the study are illustrated by the routed hydrographs of the four representative floods under each of four watershed conditions (figs. 5-8). A summary of these results, in terms of peak discharge and percent reduction, appears in table A.

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[2] Discussion by Goodrich of "Flood Routing," Rutter, Graves and Snyder, Amer. Soc. Civ. Engin. Trans. V. 104. 1939.

TABLE A.--Summary of results of four representative floods under four present and future watershed conditions

Date of flood event	Observed discharge	Routed hydrographs						
		Present conditions	With land treatment		With retarding structures		With land treatment and retarding structures	
	C. f. s.	*C. f. s.*	*C. f. s.*	*Reduction percent*	*C. f. s.*	*Reduction percent*	*C. f. s.*	*Reduction percent*
Apr. 13, 1947..	16,600	14,595	11,670	20.0	10,295	29.5	8,885	39.1
June 23, 1943..	[1] 36,900	23,115	18,065	21.8	14,020	39.3	11,045	52.2
June 1, 1941...	51,800	52,280	42,180	19.3	23,280	55.5	19,580	62.5
July 12, 1951..	[2] 130,000	93,500	82,240	12.0	53,770	42.5	46,370	50.4

[1] Original USGS estimates of 24,100 c. f. s. were revised to 36,900.
[2] Based on slope-area computation.

The above data were plotted and curves drawn (fig. 9) to illustrate the relative effectiveness of the program with respect to the magnitude of peak discharge.

The results indicate that the land treatment will reduce small floods by about 20 percent, and this effectiveness decreases as flood magnitude increases. The structures have practically no effect on a flood small enough to pass unimpeded through the outlet. Their effectiveness increases with the size of the flood up to a maximum of about 55 percent at the point where emergency spillway discharge begins, and thereafter drops off with further increase in size. The curves, based on analysis of four storms, may not be generally applicable to all storms because differences in rainfall distribution might result in slightly different effects of the structures. Differences in rainfall distribution and season of the year would certainly affect the reductions due to land treatment. However, the curves should be reasonably representative for storms occurring during April through July, during which about 90 percent of the crop and pasture damage occurred for the 13 years of streamflow record.

An estimate of the total cost of the retarding reservoirs was based on actual construction costs of similar structures built in Kansas in 1954 which averaged $0.35 per cubic yard. This was raised to $0.40 per cubic yard in making this estimate. Engineering costs, contingencies, and overhead averaged 40 percent of construction costs. The total cost of the retarding structures based on $0.56 per cubic yard of fill is $5,757,600.

An estimate of existing damages in the watershed and the reduction which would be effected by land treatment and structures was made to provide a measure of the effect of them on downstream flood damages in areas of this size, and some measure of the feasibility of the program. This estimate was developed from a detailed appraisal of crop and pasture damage on the main stem and major tributaries and a less detailed analysis of other agricultural and road and bridge damage based on the damages which resulted from the 1951 flood. A summary of these evaluated damages and benefits converted to long-term projected prices appears in table B.

TABLE B.--Summary of damages and benefits under present and future watershed conditions

Average damages per year[1]

Watershed condition	Damages to--			
	Crop and pasture	Other agriculture	Roads and bridges	Total
	Dollars	*Dollars*	*Dollars*	*Dollars*
Present condition......................	243,750	82,670	6,990	333,410
With land treatment only...............	180,200	63,430	6,300	249,930
With structures only...................	108,280	38,420	2,440	149,140
With structures and land treatment.....	85,990	29,000	1,750	116,740

Average benefits per year[1]

Watershed condition	Crop and pasture	Other agriculture	Roads and bridges	Total
With land treatment only...............	63,550	19,240	690	83,480
With structures only...................	135,470	44,250	4,550	184,270
With structures and land treatment.....	157,760	53,670	5,240	216,670

[1] For the 13 years of record.

The average damage per year for the 13 years of streamflow record is $333,410 under existing watershed conditions. Based on the computed reductions in discharge, this damage would be reduced to $249,930 per year with the land treatment, to $149,140 per year with the structures alone, or to $116,740 per year with land treatment and structures combined.

No attempt was made to evaluate damage or benefits to urban areas, public utilities, pipelines, or railroads; to minor tributary areas to which the Department of Agriculture studies have ordinarily given greatest attention; or to the main stem flood plain below the Toronto Dam site. Sediment damage and streambank cutting were not evaluated, and no attempt was made to estimate benefits which would accrue through increased use of flood-plain land. On the basis of more detailed studies made of comparable watersheds in this area, these unevaluated items might represent about one-half of the total damages and benefits in the watershed.

Appendix I
Detailed analysis of procedure

Basic data

All practical use was made of the data collected in the area by other agencies.

The Tulsa District Office of the U. S. Corps of Engineers initiated a survey of the watershed in 1940, relative to the analysis of a reservoir project near Toronto, Kans. These data, confined to the main stem of the Verdigris River, include stream and valley cross sections, streambed and low-water profiles, and 1951 and 1948 flood profiles based on high watermark surveys. In cooperation with the U. S. Geological Survey, the Corps has collected 13 years of streamflow data from a stream gage near Coyville, Kans., at a drainage area of 747 square miles. From this record, the stage hydrographs were worked up for all floods exceeding peak stage of 28.0 feet, the corresponding stage-discharge rating curves, and the annual flow charts of all years of record at the Coyville gage.

Rainfall data for all floods of record were obtained for gages in and near the watershed from the Climatological Bulletins published by the U. S. Weather Bureau.

The Kansas Division of Water Resources has made a study of a detention-reservoir program on Homer Creek, in the Verdigris River watershed. They have made planetable surveys of about 150 reservoir sites, 15 of which have been included in this study. The data for the 15 sites, including the area and storage-volume calculations, were made available. The Kansas Division of Water Resources also furnished supplementary rainfall data on the storm of July 1951.

In addition to the data already available from previous surveys in the watershed, it was necessary to obtain more information.

Fifty-one channel and valley cross sections, a sample of which is in figure 10, were surveyed on the main stem and tributaries to supplement 18 main stem cross sections previously surveyed by the Corps, making a total of 69 cross sections to be used for determining channel and valley characteristics. At 40 of the 51 surveyed cross sections, high watermark elevations were obtained for the July 1951 flood. All the sections were tied to sea-level datum for plotting of stream profiles (fig. 11) and computation of channel and valley slope.

A map and field study was made to locate all suitable reservoir sites in the watershed. One hundred and forty-seven sites were tentatively selected. By considering all possible sites, a practically uniform distribution throughout the watershed was obtained. Six of the sites were eliminated because they did not meet the criteria. The remaining 141 sites vary in drainage area controlled as follows: 85 sites control less than 2 square miles, 36 sites control 2 to 5 square miles, 16 sites control 5 to 10 square miles, and 4 sites control 10 to 20 square miles. The average controlled area per site is 1,800 acres, or about 2.8 square miles. A 5-foot contour interval topographic map of each site and a 10-foot contour interval map of each reservoir area were reproduced by means of a Kelsh plotter using aerial photographs and measured field-control points. This work was done by the Cartographic Unit of the Soil Conservation Service Office at Lincoln, Nebr.

Rainfall analysis

All available rainfall data were collected and analyzed for each of the four storms. This included tabulating daily rainfall from all stations (fig. 12) for 7 days before and 2 days after the flood peak. Hourly rainfall was also tabulated for this period for all recording stations. Bar graphs were made of the available recording-gage data (figs. 13-16). These data were used to determine, for each of the four storms for each of the 28 subareas, the following (tables 2-5):

1. Excess precipitation.
2. Time of beginning and duration of excess rainfall.
3. Antecedent rainfall index (index of soil moisture).

Excess precipitation was considered to be that which exceeded 0.10 inch in 1 hour. Total storm rainfall for each subarea was determined from isohyetal maps developed from data from all the stations in and adjoining the watershed (figs. 17-24). Representative recording rain gages were used as a guide in determining the hourly amounts of excess precipitation for the subareas. The selection of the representative gage was based on topography, distance, total rainfall for the major storm period, and apparent direction of travel of the storm. It was assumed that the magnitude of the hourly precipitation on the subarea was in the same ratio to the hourly precipitation at the gage as the total precipitation on the subarea was to the total precipitation at the gage. The total of the hourly amounts of excess precipitation then represented the excess precipitation for the storm period for the subarea.

Time of beginning and duration of excess precipitation for each subarea was assumed to be similar to the time of beginning and duration of excess precipitation at the chosen representative recording rain gage. The beginning and duration of excess on the subarea were adjusted from the pattern at the recording gage to reflect apparent travel direction of the storm and to account for those periods in which there was excess precipitation at the gage but not as computed for the subarea. One hour with less than 0.10 inch of rain constituted a break between rainfall periods.

A numerical antecedent rainfall index was computed by the following equation:

$$M = P_1 + \frac{P_2}{2} + \frac{P_3}{3} + \frac{P_4}{4} + \frac{P_5}{5} \qquad (1)$$

Where:

M = antecedent rainfall index

P = daily precipitation in inches for the days preceding the flood indicated by the subscripts 1 to 5

For consecutive rainfall periods during a day, the amount of rain in the first period was added to the rainfall for the first preceding day in determining the index for the second period. Likewise, the rainfall for the first and second period was added to that of the first day when determining the index for the third period. The amounts of daily rainfall from a representative gage were used to compute the antecedent rainfall index for subareas except for the days for which the subarea rainfall had been computed from isohyetal maps.

Analysis of runoff from subareas

A detailed analysis was made of the runoff from each of the four selected floods for each of the 28 subareas, particularly as to the areal distribution of soil and cover types, season of the year, storm duration and intensity, and antecedent moisture conditions. These factors are embodied in the following empirical formula[1]:

$$Q = P\left[1 - (10)^{-BP}\right] \qquad (2)$$

Where:

Q = volume of surface runoff in inches

P = volume of excess precipitation in inches

B = runoff index determined by the following formula:

$$\operatorname{Log} B = -1.429 - 1.990 \log T - 1.333 \log D + 0.229\,M + 1.061 \log C - 2.271\,\frac{S}{D} \qquad (3)$$

Where:

B = runoff index

T = seasonal index

D = duration of storm period in hours

M = 5-day antecedent rainfall index

C = cover-practice index

S = soil index

Equation (3) was solved by the use of the nomograph of figure 25 in which the watershed and storm characteristics were estimated as follows:

(1) The seasonal index (T) was computed for each of the four storms by the formula:

$T = \frac{A_{90}}{F}$ in which A_{90} is the average daily air temperature for 90 days previous; and F is the mean annual temperature for the watershed area.

Following are the seasonal indices computed for the four storms:

Date of plot	Seasonal index
April 13, 1947	0.90
June 23, 1943	1.20
June 1, 1941	1.20
July 12, 1951	1.45

(2) The duration of storm period (D) and 5-day antecedent rainfall index (M) were obtained as discussed in Rainfall Analysis.

(3) The cover-practice index (C) is a measure of the relative runoff from major cover and condition classes. The cover-practice index for each subarea was computed by weighting of the cover-practice index for each part of the subarea by the area occupied by each cover practice (table 6). The data on cover and practices were obtained by a watershed inventory made by the State Conservationist's staff in Kansas.

(4) The soil index (S) is a measure of the relative runoff from major hydrologic soil groups. The soil index for each subarea was computed by weighting of the infiltration index for each hydrologic soil group in the subarea by the area occupied by the soil group (table 7). These data were also compiled by the Kansas State Conservationist's office.

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[1] Unpublished appendix to House Document No. 388, 82d Congress 2d Session, Interim Survey Report, Grand (Neosho) River watershed.

Substitution of the proper values for the factors in equation (3) resulted in the runoff index (B). The equation was solved by the nomograph of figure 25.

Equation (2) is then solved by entering the chart of figure 26, using the precipitation values for the excess periods as discussed in Rainfall Analysis and the (B) values as determined above. The volumes of surface runoff thus obtained for each of the subareas for each of the four storms are in tables 2-5.

The total volume of surface runoff from the 28 subareas as computed above was compared with the volume of surface runoff at the Coyville gage, as computed by subtracting base and subsurface flow from the recorded volume. This provides a check on the accuracy of the magnitude of the factors used in estimating the surface runoff from the subareas. Where the estimate of subarea runoff could be improved by proper revision of the factors, within the bounds of possible choices, such revisions were made and the subarea runoff recomputed. After such revisions were made, the computed volume varied less than 2.5 percent from the measured volume for each of the storms.

The volume of direct runoff for subareas determined in the procedures previously mentioned represented present watershed conditions. It was computed with the land treatment assumed to be in effect (tables 2-5).

Triangular outflow hydrographs were computed for subareas for the four storms. These computations were based on subarea characteristics expressed in the following equations:[2]

$$R = \frac{483A}{\frac{D}{2} + T_l} \qquad (4)$$

$$T_l = 0.61\ T_c \qquad (5)$$

$$T_p = T_l + \frac{D}{2} \qquad (6)$$

$$T_r = 1.67\ T_p \qquad (7)$$

$$q = Q\,R \qquad (8)$$

Where:

R = peak rate of discharge in cubic feet per second for 1 inch of runoff

A = drainage area in square miles

D = duration of storm period in hours

T_l = time in hours from the center of mass of inflow or excessive rainfall to peak of outflow.

T_c = time of concentration (time from center of mass of inflow to center of mass of of outflow) in hours

T_p = time from beginning of runoff to peak rate of runoff in hours

T_r = time from peak rate of runoff to end of runoff, in hours, for a triangular hydrograph

q = peak rate of discharge in cubic feet per second

Q = volume of runoff in inches

The area (A) in square miles for subareas is in table 8.

The duration of storm period (D) in hours was developed in Rainfall Analysis (tables 2-5).

The time from peak inflow to peak outflow (T_l) is derived by substituting the value of T_c in equation (5) and solving for (T_l). The time of concentration (T_c) was determined at the outlet for each subarea. This was done by measuring the respective distances on a 1-inch-per-mile map and computing (T_c) by dividing the distance by the average velocity of 2.88 miles per hour. This average velocity was the average for the entire watershed based on the time of concentration to the Coyville gage as computed by the empirical equation:[3]

$$T_c = \frac{0.87}{S_{rl}} \qquad (9)$$

where S_{rl} is the slope (using common logarithms) of the recorded hydrograph recession line (as plotted on semilog paper) for storms covering the entire watershed. The average time of concentration was computed to be 32 hours.

The factors T_p, T_r, R, and q were computed from equations (6), (7), (4), and (8) respectively. Equation (4) is solved by the nomograph in figure 27. Examples of the above items as computed are shown in table 9 (for routing reach C-3), and examples of the triangular hydrographs derived therefrom in figure 28. Triangular hydrographs were drawn for each subarea for each storm period.

These computed flows, representing present conditions, were routed to Coyville by the time-conversion method as explained in Comparison of Flood-Routing Methods, Appendix II. Checks and comparisons were made with data developed from the recorded hydrograph at the Coyville gage. Refinements and obvious corrections were made and the triangular hydrographs recomputed to attain reasonable correspondence between the hydrograph obtained by routing and that derived from the Coyville gage.

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[2] Unpublished appendix to House Document No. 388, 82d Congress 2d Session, Interim Survey Report, Grand (Neosho) River watershed.

[3] Derived by Victor Mockus, Central Technical Unit, Soil Conservation Service.

Triangular outflow hydrographs were drawn as previously described to represent conditions with the land treatments assumed to be in effect.

In constructing triangular hydrographs for conditions with structures assumed to be in effect, triangular hydrographs were developed for the uncontrolled areas, and discharge from reservoirs was added. This involved routing the computed inflow through reservoirs and computing pipe discharge and spillway discharge whenever spillway discharge occurred.

Trial routings and computations indicated that pipe-discharge calculations could be based on the 4/5 or 80-percent rule.[4] This rule states that the average discharge from a pipe or culvert-type outlet during recession flow is 80 percent of the maximum discharge. Maximum pipe discharges were calculated for all reservoirs based on the Soil Conservation Service criterion for Kansas (see Retarding Reservoirs). Required pipe sizes were determined from pipe-discharge curves (fig. 29). The maximum pipe discharge for each storm was computed for each reservoir and used to compute the average discharge and the emptying time in hours. Pipe discharge from the reservoirs and runoff from the uncontrolled areas were assumed to begin, at the outlet of the subarea, at the same time. It was also assumed that average pipe discharge for the storm was attained at the outlet at the end of the first runoff period from the uncontrolled area and remained constant until the reservoir was empty. The pipe discharge was plotted at subarea outlets (fig. 30).

Emergency spillway discharge would have occurred on the upper half of the watershed during the July 1951 storm. A modified time-conversion method was used for routing spillway discharge through the individual reservoirs, and from the reservoir to the subarea outlet. The respective discharges were then combined at the subarea outlets. The time of concentration of drainage areas above the reservoirs to the outlet of the subareas was computed. This time of concentration and the area and rainfall characteristics for the July 1951 storm were then used to develop triangular hydrograph data at the subarea outlet for the reservoired areas. These data represent the inflow to a "weighted composite reservoir" at the subarea outlet. From these data, a mass-inflow curve was drawn assuming uniform inflow rate. On the same chart a mass pipe-discharge curve (from the area above reservoirs) was drawn. Then, for any inflow period volume of spillway discharge equals mass inflow minus mass pipe discharge minus reservoir storage.

Triangular hydrographs of spillway discharge were constructed. The starting point of spillway discharge was at the point where mass inflow exceeds storage plus mass pipe discharge. The peak rate for the hydrographs was computed by reducing the peak inflow on the basis of the ratio of the available spillway storage to the spillway discharge volume; figure 31 shows the ratios used in this computation. The time of the peak of the hydrograph of spillway discharge was located on the recession side of the inflow hydrograph at the point when the inflow equals the peak-outflow rate. By considering the spillway-outflow rate as uniform, the volume of spillway discharge, up to the time the peak occurred, was computed. This volume subtracted from the total volume of spillway discharge computed from the mass curves, gave the volume of spillway discharge after the peak occurred. Again, assuming a uniform spillway discharge rate, the time spillway discharge ends was computed. Figure 32 presents this method graphically, and table 10 shows sample computations. Triangular hydrographs were so constructed for conditions with the structures assumed to be in effect and for conditions with both land treatment and structures assumed to be in effect.

A comparison of the modified time-conversion method of routing, as used here, with the graphical-step method was also made (figs. 33, 34).

The results of routing reservoirs individually and combining them were compared with the results of combining and routing a composite reservoir (fig. 35).

The results of routing through a structure by the graphical-step method and downstream by the storage-indication method are compared with the triangular hydrograph constructed directly at the downstream point by the modified time-conversion method (fig. 36).

Retarding reservoirs

This section deals with site selection, site mapping, design, and costs of the retarding reservoirs.

It was the aim, in locating sites for the retarding reservoirs, to select those that would not inundate cropland, roads, bridges, utility lines, farmsteads, or other property of high value; and that would be immediately upstream from areas of potentially high flood damage. Generally, only sites having a drainage area of more than 1 square mile were to be considered.

Using the maps of the "Reconnaissance Soil Conservation Survey"[5] which show the drainage, land use, land capability, and physical features, all potential sites were located and the drainage areas estimated. A field inspection was made to determine if the required storage[6] (tentatively assumed to be 5 inches) was available, to check the use of the reservoir area and potential damages immediately below the site, and to determine the availability of the emergency spillway. Certain of the sites were discarded because of inadequacy of one or more of these factors. The Kansas Division of Water Resources had, for another study, mapped 154 sites in the Homer Creek subwatershed, and these sites were included in the above site study, selecting those that met the criteria adopted for this study.

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[4] The derivation of this rule is given in Hydraulics of the Miami Flood Control Project. Technical Report VII by S. M. Woodward, Dayton, Ohio 1920.

[5] Prepared by Soil Conservation Service in cooperation with the Kansas State Agricultural Experiment Station.

The mapping of the reservoir areas and dam sites was done by use of a Kelsh plotter, an instrument designed for stereoscopic contour mapping from aerial photographs. The maps were reproduced on a scale of about 1 inch to 500 feet, with 10-foot contour intervals for the reservoir area and 5-foot intervals at the dam site (fig. 53). Physical features such as roads, buildings, farmsteads, and utility lines, were also shown on the map. The sites studied by the Kansas Division of Water Resources had been mapped by use of plane-table methods.

The general design of the retarding structures was typical of structures being constructed by the Soil Conservation Service. The structures would be of compacted earth fill, with sodded emergency spillway, and an automatic drawdown tube to completely drain the reservoir.

Reservoir-storage requirements varied with the drainage area controlled and were based on the criteria presently being used by the Soil Conservation Service in eastern Kansas, which were:

Drainage area	Minimum storage
0-1,500 acres	3.7 inches of runoff
1,500-2,500 acres	Increases uniformly from 3.7 to 5.7 inches of runoff
2,500 acres and over	5.7 inches of runoff

The 3.7 inches of runoff have about a 4-percent chance of being equaled or exceeded in any year, and the 5.7 inches of runoff about a 1-percent chance. An allowance of 0.3 inch from the watershed was included in the capacity of each structure for sediment accumulation for a 50-year period.

Drawdown tubes were designed to discharge at a rate of 15 CSM which would empty the full reservoirs in from 7 to 11 days.

It was assumed that emergency spillways would safely discharge the flood peak of the 1-percent-chance storm occurring when the pool is full, with a maximum depth of flow of 3 feet. An additional 3 feet of freeboard and 1 foot for settlement were provided, making the top of the fill 7 feet above the spillway crest.

Storage capacity and reservoir area were computed for selected depths from the topographic maps (table 11), and curves of depth vs. storage and depth vs. reservoir area were developed (fig. 37).

After all the computations of storage and reservoir area had been completed, all the sites were again critically reviewed. Sites not capable of furnishing the required storage, or which inspection of the topographic map showed would inundate buildings, roads, or other valuable improvements, were discarded, leaving 141 structures (table 12, fig. 38).

Earth fills were tentatively designed with 2:1 and 3:1 side slopes. A minimum top width of 12 feet was used, increasing the width to 14 feet for dams 40 to 60 feet high, and to 16 feet for dams more than 60 feet. Computations of fill volumes were based on the above criteria and valley cross sections at the centerline of the dam sites as drawn from the topographic maps. A sample cross section is shown in figure 39, and sample fill calculations in table 13. Computed volumes of fill for each dam along with other retarding-structure data are in table 14.

An estimate was made of the total cost of the reservoir system (not including site costs) based on the total volume of fill. The average cost per cubic yard for structures built in Kansas by the Soil Conservation Service in 1954 was $0.35. Using a unit cost of $0.40 per cubic yard and a total fill volume of 10,280,542 cubic yards for the 141 structures, the construction cost would be $4,112,600. The engineering costs (investigation, laboratory analysis, design, and supervision) for the Kansas structures averaged 40 percent of the construction costs. Based on this percentage, the engineering costs for the 141 structures would be $1,645,000. The total construction and engineering costs would be $5,757,600.

Flood routing

A great many procedures have been devised for determining progressively the timing and shape of a flood wave at successive points along a river. Most methods which consider the storage in a river valley involve the solution either graphically or mathematically of some form of the basic storage equation ($\frac{dS}{dt} = I - q$) which says that the rate of change of storage is equal to the difference between the inflow and outflow rates.

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[6] By use of the equation $H = \sqrt[3]{CVLS}$; where H is the required dam height in feet; C is a constant varying with slope of reservoir; V is the volume of storage in acre-feet; L is the slope of the bottom of the reservoir in percent; and S is the slope of the sides of the reservoir in percent.

The equation may be expressed arithmetically in the form:

$$\frac{I_1 + I_2}{2} t - \frac{q_1 + q_2}{2} t = S_2 - S_1 \qquad (10)$$

In which:

I = inflow rate

q = outflow rate

S = the total volume in storage in the reach

t = the routing interval

subscripts 1 and 2 = the beginning and end of the period

The routing procedure selected for use in this study may be called a modified Goodrich-Wisler[7] method, which employs a graphical solution to the storage equation in the form:

$$\left(\frac{2S_1}{\Delta t} - q_1\right) + (I_1 + I_2) = \left(\frac{2S_2}{\Delta t} + q_2\right) \qquad (11)$$

In which:

S = the storage in the reach in cubic feet

I = the inflow rate, in cubic feet per second

q = the outflow rate, in cubic feet per second

Δt = the routing interval in seconds

subscripts 1 and 2 refer to the beginning and end of the routing interval

Since the storage expressed in cubic feet is an awkwardly large figure, the equation is made more workable by converting cubic feet to cubic feet per second hours; 12 cubic feet per second hours are very closely equal to 1 acre-foot; and Δt can then be expressed in hours.

To solve the storage equation, for each routing reach it is necessary to compute the channel and valley storage coincident with any given discharge in the reach. Although the storage for any discharge varies with rising or falling stage, the computation can be simplified by computing storage on the basis of steady-flow profiles. The steady-flow water-surface profile computation was based on the 1951 flood profile constructed from high watermark data obtained in the field. A sample of these water-surface profiles is shown in figure 40. Because this flood was relatively recent and was twice the discharge of any previous flood of record, local residents were able to produce many reliable high watermarks. These high watermarks were referenced to sea-level datum by a level-line survey tied to existing USGS benchmarks. Based on this survey, a water-surface profile was constructed for this flood.

The discharge corresponding to the 1951 high watermark elevation was calculated for each cross section on the basis of the computed runoff from the area above the section and the peak discharge per inch of runoff for that drainage area, based on an average relationship expressed by the formula:[8]

$$q_x = q_c \frac{A_x(\sqrt{T_{cc}} + 0.61\, T_{cc})}{A_c(\sqrt{T_{cx}} + 0.61\, T_{cx})} \qquad (12)$$

Where:

subscripts x and c signify the value at the cross section and at the Coyville gage respectively

q = peak discharge per inch of runoff in c. f. s

A = drainage area in square miles

T_c = time of concentration in hours

0.61 = a constant reflecting the weighted time of concentration

On the basis of the surveyed stream and valley cross section and the 1951 high watermark elevation and corresponding discharge, a rating curve was computed at each cross section by Manning's formula:

$$q = \frac{1.486}{n} ar^{2/3} s^{1/2} \qquad (13)$$

Slope was determined from channel and overbank distances (scaled from aerial photographs of the stream valley) and low water elevations (from the surveyed cross sections). A field investigation for each section was made to determine the approximate value of channel and overbank "n." The approximate ratio between channel and overbank "n" was maintained and the values adjusted to produce the computed 1951 discharge at the measured 1951 water-surface elevation (table 15). The variation in "n" values is accentuated by the fact that all errors inherent in the measurement of a slope, effective cross-sectional area, high watermark elevation, and discharge have been thrown into the "n" values. These adjusted "n" values were used as the average for all elevations in computing the rating curve at each cross section (table 16).

The volume of channel and valley storage between cross sections, for the required range of discharges, was computed by the average end-area method and added to determine the storage in the routing reach (table 17).

For each discharge, the value of $\frac{2S}{\Delta t}$ was computed and a curve of discharge vs. $\frac{2S}{\Delta t}$ plotted for each routing reach. By adding the value of q to $\frac{2S}{\Delta t}$ at various discharges, the curve of $\left(\frac{2S}{\Delta t} + q\right)$ vs.

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[7] Discussion by Goodrich of "Flood Routing," Rutter, Graves, and Snyder, Amer. Soc. Civ. Engin. Vol. 104, 1939.

[8] Derived by Victor Mockus, Central Technical Unit, Soil Conservation Service.

discharge was constructed for each reach. Similarly, the curve $(\frac{2S}{\Delta t} - q)$ vs. discharge was constructed for each reach. These two curves are the working curves for flood routing through each reach. A sample of these working curves is shown in figure 41. The application of these curves in solving equation (11) is in figure 41. Starting with a discharge (q_1) of 6,250 c. f. s., which corresponds to a value of 22,000 on the $(\frac{2S}{\Delta t} - q)$ curve, measure a distance $I_1 + I_2$ (40,000) horizontally as shown, move up to the $(\frac{2S}{\Delta t} + q)$ curve, and read the value of q_2 (12,000 c. f. s.) on the discharge scale. The value of q_2 then becomes q_1 in the next time interval, and the procedure is repeated. In this manner the hydrograph of outflow from the reach can be constructed from the hydrograph of inflow to the reach.

The mechanics of tabulating the computed inflow and outflow discharges at intervals of 1.5 hours is in table 18. A summation of the inflow discharges compared with a summation of the outflow discharges serves as a check on the accuracy of the routing mechanics.

As previously mentioned, the watershed was divided into subareas of, roughly, 25 square miles each, and a runoff hydrograph constructed for each. These runoff hydrographs represent the local inflow into each routing reach.

The main stem and tributaries were broken down into 21 routing reaches (fig. 42), giving consideration to the cross-sectional locations, the subwatershed unit boundaries, and the location of tributary junctions; and keeping the reach travel time as nearly as possible an even multiple of, and always greater than, the selected routing interval of 1.5 hours.

It would be desirable for accuracy and ease of calculation to have the limits of the routing reaches coincide exactly with the subwatershed boundaries and tributary junctions and at the same time to keep them of such length that the average bankfull-travel time through the reach is in each case equal to the selected routing interval of 1.5 hours. Obviously this is physically impossible to accomplish on an actual watershed. One alternative is to vary the routing interval to coincide with the reach-travel time. This, however, necessitates plotting the routed hydrograph of each reach and reading the discharges at the new time interval for the succeeding reach. By setting up the routing-reach limits so that the reach-travel time is as nearly as possible an even multiple of, and always greater than, the selected routing interval of 1.5 hours, the necessity of plotting the hydrograph at each reach is eliminated at very little sacrifice of accuracy. Routing reach 1, the upstream-routing reach on the main stem, is so located that the upper end of the reach coincides with the outlet of subarea 1. The runoff hydrograph for the subarea is, therefore, the inflow hydrograph for the routing reach. This hydrograph is routed through reach 1, as previously described, to produce the hydrograph of outflow from the reach. The runoff hydrographs for subareas draining into the stream within the limits of the routing reach are added to this outflow hydrograph, with respect to time, to produce the hydrograph of inflow into reach 2 below. This hydrograph is routed through reach 2 and the local inflow added to produce the hydrograph of inflow to reach 3. The routing progresses downstream in this manner to the Coyville gage site. The runoff from principal tributaries is routed similarly and is treated as local inflow to main stream-channel reaches.

Runoff hydrographs for the four floods, for existing watershed conditions, were routed to the Coyville gage site in this manner and appropriate base flow, as estimated from the recorded hydrograph, was added. Similarly, the runoff hydrographs, for the watershed conditions which would exist (1) with land treatment, (2) with the detention-reservoir system, and (3) with combined land treatment and detention reservoirs, were routed to the gage site. The resulting hydrographs and the recorded gage hydrograph for each of the four storms are in figures 5-8.

Land treatment

Information on land use, cover conditions, and farming practices was collected and compiled for analyzing the effect of land treatment on surface runoff. Information was not collected on specific conservation measures and their costs or on the changes in crop production that might take place as a result of a land treatment program.

For each of the subareas, an inventory was made of present land use, cover condition, and farming practices. The areas of each of the following "cover-condition classes" were obtained:

Cultivated land
  Row crops--straight
  Row crops--terraced
  Legumes, grasses and small grains--straight
  Legumes, grasses and small grains--terraced

Pasture and rangeland
  Good
  Fair
  Poor

Woodland
  Good
  Fair
  Poor

In this classification, "good," "fair," and "poor" are based on hydrologic considerations and not on forage or timber-production potentials. Areas occupied by roads, farmsteads, and towns were placed in the cover-condition class of "row crops--straight."

For each of the subareas an estimate was then made of the land use, cover conditions, and farming practices that would prevail if land treatment based on land capability were to be applied, to the extent that could reasonably be achieved. The Land Capability maps of the Kansas Reconnaissance Soil Conservation Survey were used by the local technicians in making this estimate.

The acreages of the various cover-condition classes for present conditions and future (with program) conditions are in table 19. In summarizing the data of this table, it will be noted that there will be but little change in land use: the area of cultivated land, now 20 percent of the total watershed area, will be reduced to 18 percent; pasture will increase from 76 to 78 percent; and woodland will remain the same, about 4 percent. Changes in runoff that occur because of the land treatment will largely be due to the improvement in farming practices and cover conditions. It will be noted, in referring to the "cover-practice indices" of table 19 that the program for cultivated land provides for an improvement in the "present" hydrologic condition over the "future" condition for the same practice; for example, the cover-practice index for row crops--straight for "present" is 20.4 and for "future" is 14.6. This improvement in hydrologic effectiveness is due to such practices as better rotations, better varieties of crops, and more timely farm operations. It has been considered that such practices will be applied to all the cultivated areas.

Economic studies

A detailed study was made of crop and pasture damage on the main stem and principal tributary flood plains. The flood plains of drainage areas less than about 25 square miles were not included. Present damage was computed by reaches for each flood in the 13-year record and converted to an average damage per year for the period. (This is not the same as the average annual damage, to the extent that the 13 years of record is not representative of normal conditions.) Computations were made of damages that would exist with each of the three conditions of watershed treatment in effect.

Estimates were also made of other agricultural damages, such as to farm buildings, livestock, stored crops, etc., and of damages to roads and bridges. The studies on which these estimates were based were considerably less detailed than the study of crop and pasture damages. Present damages and the damages that would exist with the three conditions of watershed treatment were estimated--as for crop and pasture damage. No estimates were made of other types of damage, such as to urban areas, communication facilities, etc. The benefits which would accrue from changes in cropping pattern on the flood plain were not estimated.

To compute crop and pasture damages, maps were prepared showing land use and crop distribution for the entire flood-plain area and for the area extending about a half mile above all retarding structure sites. This mapping was done in the field on aerial photographs, and the strip map (fig. 4) was prepared from these photographs. From this strip map, the area in each land use and crop was determined for each routing reach.

Crop-yield data were secured from the State Agricultural Statistician, by counties, for a 23-year period. Based on these data and interviews with about 20 percent of the farmers concerned, and with local agricultural technicians, the average yields for years in which there were no floods were established for the major crops in the flood plain. Similarly costs of production for each crop were established.

Crop values and production costs were computed, using the 1952 average prices paid and received by farmers, as determined from the mid-month prices provided by the office of the State Agricultural Statistician. Long-term prices were about 75 percent of the 1952 averages, and this factor was used in converting total damages and benefits to long-term prices.

For each reach, the flood-free yield for each crop was weighted by the percentage of each crop in the reach; this weighted yield was multiplied by the value per unit of yield to give a weighted damageable value per acre for each crop; these values were then totaled to give a composite damageable value per acre for the reach (table 20).

Making appropriate allowances for production costs not incurred, the percent of damage which each crop would suffer from inundation to depths of 0 to 1 foot, 1 to 3 feet, and more than 3 feet was determined for each month of the year, by use of data developed over several years by the Fort Worth, Tex., and Lincoln, Nebr., Soil Conservation Service Engineering and Watershed Planning Units. These percent-damage factors were checked in the field by interviews with farmers and agricultural technicians in the area. A composite damage per acre for each reach by depth classes and months was computed by use of these percent-damage factors (table 21).

Discharge vs. area-flooded curves were drawn for each cross section for each depth class. A sample curve is in figure 43, and the data for all cross sections are in table 22. The area flooded in each depth class was computed for each reach for the floods of record. These acreages were multiplied by the appropriate composite-acre damage and added to determine the damage from each flood of record for the reach. The damage for all reaches was added to give the total watershed damage.

To eliminate the effect of recurrent flooding, this total damage was modified by use of a factor[9] based on the relationship between average acres flooded annually and the total flood-plain area. The factor ranged by reaches from about 72 to 92 percent. The remaining damage was converted to an average damage per year for the 13-year period by dividing by 13, and to long-term prices by multiplying by 0.75. Thus computed, the average damage per year is $243,750.

Based on the flood routings of the 4 floods under the 3 conditions of treatment, i.e., with land treatment, with reservoirs, and with both land treatment and reservoirs, the reduced discharge was computed for each flood in the series and the corresponding reduced average damage per year for the 13 years computed. The average crop and pasture damages as computed for present conditions and for the three conditions of treatment are in table 23. The computed flood-prevention benefits are also shown.

Other agricultural damages were computed for the 1951 flood by use of data obtained by interview with farmers (table 24). It was assumed that the ratio of the other agricultural damage to crop and pasture damage (25.3 percent) for the 1951 flood would apply to floods of any size occurring in the same month (July). Other agricultural damage was computed on this basis for the other July floods in the series to establish a damage-discharge relationship curve (fig. 44). This damage-discharge curve was then used to estimate the damage for all other floods in the series. Only about seven of the larger floods in the series caused appreciable damage. By this expedient, the average damage per year, on a long-term price basis, was estimated to be $82,670, under present conditions; $63,430 with land treatment only; $38,420 with structures only; and $29,000 with both land treatment and structures.

The damage to roads and bridges from the 1951 flood was obtained by interview with county engineers and estimated to be $121,000. Information for other floods was not available; however damages from these floods were thought to be relatively small. An average damage per year for the period of record was therefore computed by dividing by 13. Thus computed, the average damage per year on a long-term price basis amounts to $6,990. Damages for conditions with the program were roughly estimated by basing the reductions in damages on reductions in discharge. Thus estimated damages remaining with land treatment only were $6,300; with structures only $2,440; and with both land treatment and structures $1,750.

The total of the evaluated damages on the flood plains of the main stem and principal tributaries, under present conditions, amounts to $333,410 per year for the 13-year period; with land treatment only $249,930; with structures only $149,140; and with both land treatment and structures $116,740.

Damage to land by deposition of sediment was not evaluated. This type of damage is believed to be relatively insignificant in this area.

Flood damages to crops and pasture cause an indirect damage through loss of business in the community. Other indirect damages attributable to floods include losses resulting from delay or rerouting of transportation, relief and rehabilitation of flood victims, and similar items. However, indirect damages were not computed.

Reductions of flood frequencies would permit more intensive use of flood-plain lands; however these possible benefits were not evaluated.

Appendix II
Related Investigations

Comparison of flood-routing methods

The modified Goodrich-Wisler method of flood routing was selected for use in this study. Other less laborious methods, however, will give comparable results. For example, the method of computing the triangular runoff hydrographs for the subareas, as presented in Appendix I, Analysis of Runoff from Subareas, can be used to reproduce a flood hydrograph at the Coyville gage. This can be done by computing, for each subarea, the hydrograph which would be produced at the Coyville gage site if runoff occurred from that subarea only. The peak and base length are computed as described in Appendix I, substituting the time of concentration to the gage site for the time of concentration of the subarea. This longer time of concentration will, of course, result in a triangular hydrograph of lower peak and longer base length. Travel time from the head of the subarea was used as time of concentration since comparisons show that this introduces no measurable error in results.

The hydrograph is transposed in time an amount equal to the travel time from the subarea outlet to the gage. This is referred to as the time-conversion method of flood routing.[1]

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[9] The derivation of these factors is explained in the Pond Creek Study, Appendix IV, p. 28.

[1] Unpublished Appendix, Interim Survey Report, Grand (Neosho) River Watershed; Program for Runoff and Waterflow Retardation and Soil Erosion Prevention, by U. S. Department of Agriculture April 1950, also "Hydrology Guide" of the Soil Conservation Service.

In determining translocation time, the beginning of runoff was used as the control or starting point. An example of the data used in constructing the subarea 5 hydrograph at Coyville is in table 25 and samples of the computed hydrographs in figure 45.

By this method the triangular hydrographs representing the runoff at the Coyville gage for each of the 28 subareas were constructed for each of the 4 storms. These triangular hydrographs are added with respect to time to produce the total watershed hydrograph at the gage site. The hydrographs produced by this method are compared with those produced by storage routing in figures 46-49.

This time-conversion method of routing was used to provide a quick check on the total volume, time, and rate of runoff from the subareas. When indicated, adjustments were made in time, amount or intensity of excess rainfall, or in the antecedent rainfall index. These factors were determined by interpolation and extrapolation and were therefore subject to a reasonable amount of revision.

Interrelationship of precipitation, discharge, surface runoff, and base and subsurface flow

A brief analysis of the interrelationship of precipitation, discharge, surface runoff, and base and subsurface flow was made as a matter of general interest. Some of the results are presented here to help the reader as a means of comparing this watershed with others with which he may be familiar.

All of the flood hydrographs recorded at the Coyville gage were plotted, and base and subsurface flow was separated graphically from surface runoff (fig. 50). The volumes of the component flows were computed as in table 26. The average watershed precipitation contributing to each flood hydrograph was determined from precipitation records of stations in and near the watershed.

The values of average precipitation, peak discharge, surface runoff, base and subsurface flow, and precipitation minus surface runoff are tabulated for each flood of record in table 27.

The most obvious factor affecting the relationship of peak discharge to volume of surface runoff is storm duration. Assuming a straight-line relationship through zero, the linear-regression lines were computed for 1-, 2-, and 3-day duration storms. The equations expressing these relationships are: $q_1 = 17{,}245\ Q_{sr}$; $q_2 = 14{,}470\ Q_{sr}$; and $q_3 = 12{,}000\ Q_{sr}$, respectively, (fig. 51). In computing the 2- and 3-day duration curves, one questionable point was omitted from the data.

Figure 52 indicates the relationship of base and subsurface flow to precipitation minus surface runoff. The plotted points only are shown to indicate that some relationship may exist between these two quantities.

Comparison of methods of topographic mapping of reservoir sites

Topographic maps of the reservoir site areas were required for the estimation of storage volume, pool area, and fill yardage for each of the 141 proposed sites. Planetable maps of 15 of the sites had previously been made by the Kansas Division of Water Resources in the course of their study of the Homer Creek watershed in 1951-52. Storage volume, pool area, and fill yardage had been computed for these sites, and these figures were made available to us.

The remaining 126 sites were mapped from aerial photographs and field-control points by means of a Kelsh plotter.[2] Storage volume, pool areas, and fill yardage were also computed for these sites.

The average cost per site for planetable mapping was about $60. The average cost of maps by Kelsh plotter was $43 per site, including $20 for fieldwork.

To provide a measure of the relative accuracy of the 2 methods, 3 of the sites, Kansas Division of Water Resources Nos. K33 (fig. 53), K38, and K53, previously mapped by planetable were also mapped by Kelsh plotter. It should be noted that the contours on each of the two comparable maps are based on assumed datum and are not necessarily at the same actual elevation. For this reason, the maps alone do not provide an adequate comparison of the 2 methods. The best test of comparability is in the curves of storage volume vs. fill yardage (fig. 54).

The data obviously are too limited to be conclusive, and no check is available to provide a measure of the absolute accuracy of either method. It is to be expected that the discrepancy between the two methods will be greater in areas of flatter topography as represented by site K53. It is probably reasonable to assume that discrepancies in the computed data for individual reservoirs would be compensating, and the two methods would result in similar answers for the program as a whole.

Downstream effect of program

The study indicates the effect of the proposed program on peak discharge at Coyville. An estimate of the effectiveness of the program on reducing the 1951 flood downstream was obtained by routing this flood downstream to the Altoona gage (a distance of about 40 river miles). The watershed above this point has a drainage area of 1,138 square miles. Limitations of time and data prevented the use of the storage-routing method in making this determination. The Wilson Method[3] was used to give an estimate of the downstream effects at Altoona.

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[2] Work was done by the Cartographic Division, Soil Conservation Service, Lincoln, Nebr.

The Wilson "T" factor was based on the time between the center of mass of the recorded 1951 flood hydrographs at Coyville and at Altoona. Trial routings were made to determine the storage modification which most adequately reproduced the recorded hydrograph at Altoona. The local inflow between Coyville and Altoona was estimated by routing the recorded hydrograph at Coyville down to Altoona. The difference between this routed hydrograph and the recorded graph at Altoona was considered to be local inflow.

The hydrographs produced by storage routing to Coyville for present conditions and with the program were then routed to Altoona by the Wilson Method. The local inflow, as previously computed, was added to both hydrographs. The recorded and the routed hydrographs at the Altoona gage are in figure 55. A comparison of the two routed hydrographs indicates that the land treatment and structures above Coyville would effect a 42-percent reduction in the 1951 flood peak at Altoona. The area above Coyville is about 65 percent of the total area above Altoona. The area above structures is 53 percent of the area above Coyville, and 35 percent of the area above Altoona.

Similarly the 1951 flood was routed to Independence, Kans., which is approximately 75 river miles below Coyville. The recorded and routed hydrographs are in figure 55. The land treatment and structures applied on the area above Coyville would reduce the 1951 flood peak 25 percent at Independence. The area above Coyville is 26 percent and the area above waterflow-retarding structures is 14 percent of the total area above Independence.

It is probable that the program would be less effective on a more uniformly distributed storm. The 1951 storm was concentrated on the upper end of the watershed, and comparatively little rainfall occurred on the untreated area below Coyville. On the other hand, the rainfall and runoff quantities were so large as to produce spillway discharge in the upper part of the watershed. The structures would be more effective in reducing a storm which did not exceed design capacity of the storage reservoir.

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[3] Wilson, W. T. A graphical method of flood routing. Amer. Geophys. Union Trans. Part III. August 1941.

TABLE 1.--Observed peak discharges at USGS stream gage, Verdigris River near Coyville, Kans.

(All peaks above 28.0-ft. stage--1940-52)

Date of peak and hour	Peak discharge
	C. f. s.
March 10, 1952, 9:00 p.m.	9,310
March 19, 1952, 8:30 a.m.	8,400
April 23, 1952, 12:30 a.m.	8,210
May 2, 1951, 5:00 a.m.	13,200
June 24, 1951, 6:00 p.m.	12,200
June 30, 1951, 5:00 a.m.	46,400
July 4, 1951, 5:00 a.m.	10,500
July 12, 1951, 1:00 a.m.	130,000
August 27, 1951, 5:30 p.m.	8,100
September 6, 1951, 6:00 a.m.	19,000
September 9, 1951, 7:00 p.m.	8,200
September 13, 1951, 9:00 a.m.	14,200
July 11, 1950, 4:30 a.m.	10,300
July 17, 1950, 1:00 p.m.	12,100
August 1, 1950, 1:00 a.m.	8,980
August 30, 1950, 5:30 a.m.	8,830
January 24, 1949, 9:00 p.m.,	7,250
March 31, 1949, 1:00 a.m.	10,500
April 27, 1949, 10:00 p.m.	7,550
July 24, 1949, 2:00 a.m.	13,200
July 20, 1948, 9:30 p.m.	65,500
March 13, 1947, 11:00 p.m.	12,000
April 5, 1947, 4:30 p.m.	11,500
April 11, 1947, 1:00 a.m.	9,270
April 13, 1947, 12:00 p.m.	16,600
June 27, 1947, 11:30 p.m.	8,660
April 23, 1946, 4:30 a.m.	10,600
March 25, 1945, 8:30 a.m.	27,800
April 11, 1945, 12:00 p.m.	10,300
April 16, 1945, 12:30 p.m.	67,000
April 26, 1945, 3:00 p.m.	9,490
May 25, 1945, 10:00 p.m.	8,150
October 1, 1945, 5:00 a.m.	16,600
March 18, 1944, 3:30 p.m.	7,560
March 22, 1944, 4:00 p.m.	7,560
April 11, 1944, 6:30-8:30 a.m.	30,000
April 23, 1944, 1:30-2:30 p.m.	40,300
December 5, 1944, 12:00 M	19,200
May 19, 1943, 6:00 p.m.	27,300
May 24, 1943, 12:00 M	13,300
June 9, 1943, 12:00 M	10,100
June 23, 1943, 4:00 a.m.	36,900
April 10, 1942, 7:00 a.m.	8,430
April 28, 1942, 12:00 N	10,650
June 25, 1942, 11:30 p.m.	13,600
September 6, 1942, 3:00 a.m.	11,700
October 4, 1942, 12:00 p.m.	9,300
December 27, 1942, 3:00 p.m.	9,200
April 15, 1941, 2:00 a.m.	8,375
June 1, 1941, 8:00 p.m.	51,800
June 10, 1941, 8:00 a.m.	17,500
September 7, 1941, 4:30 p.m.	15,200
October 1, 1941, 12:00 a.m.	8,000
October 21, 1941, 9:00 a.m.	10,000
November 1, 1941, 8:00 a.m.	10,700
April 17, 1940, 12:00 N	7,240

TABLE 2.--Data used to calculate runoff by subareas for the April 13, 1947, storm

Sub-area No.	Date	Time	Duration of storm (D)	Antecedent rainfall index (M)	Runoff index (B)		Excess rainfall (P)	Runoff (Q)	
					Present condition	With conservation		Present condition	With conservation
			Hours				*Inches*	*Inches*	*Inches*
1.....	April 12	10:00 p.m.	2	1.37	0.28	0.22	1.1	0.55	0.47
	April 13	9:00 a.m.	2	2.36	.49	.37	.50	.22	.17
	April 13	1:00 p.m.	1	2.86	1.70	1.00	.50	.50	.36
2.....	April 12	10:00 p.m.	2	1.37	.33	.24	1.0	.53	.42
	April 13	9:00 a.m.	2	2.36	.55	.40	.50	.24	.15
	April 13	1:00 p.m.	1	2.86	1.60	1.10	.50	.45	.32
3.....	April 12	10:00 p.m.	2	1.37	.36	.24	.90	.48	.35
	April 13	9:00 a.m.	2	2.36	.59	.40	.40	.17	.12
	April 13	1:00 p.m.	1	2.86	1.80	1.00	.40	.40	.27
4.....	April 12	10:00 p.m.	2	1.37	.26	.20	1.1	.53	.44
	April 13	9:00 a.m.	2	2.36	.45	.32	.50	.20	.15
	April 13	1:00 p.m.	1	2.86	1.20	.80	.50	.50	.30
5.....	April 12	10:00 p.m.	2	1.37	.29	.22	1.1	.57	.47
	April 13	9:00 a.m.	2	2.36	.50	.38	.50	.22	.17
	April 13	1:00 p.m.	1	2.86	1.20	.95	.50	.45	.32
6.....	April 12	10:00 p.m.	2	1.37	.35	.24	.90	.47	.35
	April 13	9:00 a.m.	2	2.36	.58	.41	.40	.17	.13
	April 13	1:00 p.m.	1	2.86	1.80	1.10	.40	.40	.27
7.....	April 12	10:00 p.m.	2	1.37	.34	.23	1.1	.63	.49
	April 13	9:00 a.m.	2	2.36	.56	.40	.50	.23	.18
	April 13	1:00 p.m.	1	2.86	1.60	.95	.50	.50	.33
8.....	April 12	10:00 p.m.	2	1.37	.35	.25	1.1	.65	.52
	April 13	9:00 a.m.	2	2.36	.60	.42	.50	.25	.19
	April 13	1:00 p.m.	1	2.86	1.80	1.10	.50	.50	.38
9.....	April 12	10:00 p.m.	2	1.37	.38	.26	1.0	.59	.45
	April 13	9:00 a.m.	2	2.36	.65	.43	.50	.22	.16
	April 13	1:00 p.m.	2	2.86	.85	.57	.50	.26	.20
10.....	April 12	10:00 a.m.	3	.87	.16	.11	1.1	.37	.26
	April 12	10:00 p.m.	2	1.37	.33	.25	1.2	.72	.60
	April 13	9:00 a.m.	2	2.36	.56	.38	.60	.28	.21
	April 13	1:00 p.m.	2	2.86	.72	.49	.60	.33	.25
11.....	April 12	10:00 p.m.	2	1.37	.40	.26	1.1	.71	.53
	April 13	9:00 a.m.	2	2.36	.68	.44	.50	.27	.20
	April 13	1:00 p.m.	2	2.86	.85	.57	.50	.31	.24
12.....	April 12	10:00 p.m.	2	1.37	.37	.25	1.1	.67	.51
	April 13	9:00 a.m.	2	2.36	.64	.44	.50	.27	.20
	April 13	1:00 p.m.	2	2.86	.81	.56	.50	.30	.23
13......	April 12	10:00 p.m.	2	1.37	.37	.25	1.1	.67	.51
	April 13	9:00 a.m.	2	2.36	.64	.43	.50	.27	.20
	April 13	1:00 p.m.	2	2.86	.80	.54	.50	.30	.23
14.....	April 12	10:00 a.m.	3	.87	.18	.13	1.1	.40	.31
	April 12	10:00 p.m.	2	1.37	.35	.25	1.3	.84	.68
	April 13	9:00 a.m.	2	2.36	.63	.42	.55	.31	.23
	April 13	1:00 p.m.	2	2.86	.80	.55	.55	.35	.27
15.....	April 12	10:00 a.m.	3	.87	.17	.12	1.1	.38	.28
	April 12	10:00 p.m.	2	1.37	.35	.24	1.2	.75	.58
	April 13	9:00 a.m.	2	2.36	.60	.40	.55	.29	.22
	April 13	1:00 p.m.	2	2.86	.78	.53	.55	.34	.27
16.....	April 12	10:00 a.m.	3	.87	.15	.11	1.1	.34	.26
	April 12	10:00 p.m.	2	1.37	.32	.23	1.2	.69	.56
	April 13	9:00 a.m.	2	2.36	.55	.38	.55	.27	.21
	April 13	1:00 p.m.	2	2.86	.71	.48	.55	.33	.24
17.....	April 12	10:00 a.m.	3	.87	.17	.11	1.1	.38	.27
	April 12	10:00 p.m.	2	1.37	.35	.23	1.2	.75	.56
	April 13	9:00 a.m.	2	2.36	.56	.40	.55	.27	.22
	April 13	1:00 p.m.	2	2.86	.75	.53	.55	.33	.27
18.....	April 12	10:00 a.m.	3	.87	.18	.12	1.1	.40	.29
	April 12	10:00 p.m.	2	1.37	.36	.24	1.4	.96	.74
	April 13	9:00 a.m.	2	2.36	.59	.42	.60	.33	.27
	April 13	1:00 p.m.	2	2.86	.80	.55	.60	.40	.37
19.....	April 12	10:00 a.m.	3	.87	.18	.12	1.1	.40	.28
	April 12	10:00 p.m.	2	1.37	.37	.25	1.3	.87	.68
	April 13	9:00 a.m.	2	2.36	.62	.42	.55	.30	.23
	April 13	1:00 p.m.	2	2.86	.82	.55	.55	.35	.27
20.....	April 12	10:00 a.m.	3	.87	.19	.12	1.1	.42	.28
	April 12	10:00 p.m.	2	1.37	.38	.25	1.4	.99	.77
	April 13	9:00 a.m.	2	2.36	.63	.42	.60	.35	.27
	April 13	1:00 p.m.	2	2.86	.84	.55	.60	.41	.32
21.....	April 12	10:00 a.m.	3	.87	.16	.11	1.1	.37	.27
	April 12	10:00 p.m.	2	1.37	.33	.23	1.3	.80	.63
	April 13	9:00 a.m.	2	2.36	.55	.38	.55	.27	.21
	April 13	1:00 p.m.	2	2.86	.74	.49	.55	.32	.25
22.....	April 12	10:00 a.m.	3	.87	.16	.11	1.1	.37	.27
	April 12	10:00 p.m.	2	1.37	.33	.23	1.3	.80	.63
23.....	April 12	10:00 a.m.	3	.87	.16	.11	1.1	.37	.27
	April 12	10:00 p.m.	2	1.37	.33	.23	1.4	.90	.72
24.....	April 12	10:00 a.m.	3	.87	.19	.12	1.1	.42	.28
25.....	April 12	10:00 a.m.	3	.87	.15	.11	1.1	.35	.27
	April 12	10:00 p.m.	2	1.37	.32	.23	1.4	.89	.72
26.....	April 12	10:00 a.m.	3	.87	.16	.11	1.1	.37	.27
	April 12	10:00 p.m.	2	1.37	.33	.22	1.4	.90	.70
27.....	April 12	10:00 a.m.	3	.87	.14	.10	1.1	.33	.27
	April 12	10:00 p.m.	2	1.37	.27	.21	1.4	.80	.68
28.....	April 12	10:00 a.m.	3	.87	.18	.12	1.1	.40	.28

TABLE 3.--Data used to calculate runoff by subareas for the June 23, 1943, storm

Sub-area No.	Date	Time	Duration of storm (D)	Antecedent rainfall index (M)	Runoff index (B)		Excess rainfall (P)	Runoff (Q)	
					Present conditions	With conservation		Present conditions	With conservation
			Hours				*Inches*	*Inches*	*Inches*
1.....	June 21	11:00 p.m.	1	0.38	0.20	0.15	0.45	0.09	0.07
	June 22	5:00 a.m.	1	1.15	.30	.23	1.08	.56	.46
	June 22	7:00 a.m.	2	2.95	.38	.30	.43	.13	.11
	June 22	12:00 m.	1	3.66	1.15	.85	.23	.23	.08
	June 23	1:00 p.m.	1	4.03	1.40	1.10	.08	.08	.08
2.....	June 21	11:00 p.m.	1	.38	.23	.16	.47	.12	.08
	June 22	5:00 a.m.	1	1.15	.34	.24	1.12	.65	.51
	June 22	7:00 a.m.	2	2.95	.44	.31	.45	.17	.12
	June 22	12:00 m.	1	3.66	1.30	.90	.24	.24	.10
	June 23	1:00 p.m.	1	4.03	1.60	1.10	.08	.08	.08
3.....	June 21	11:00 p.m.	1	.38	.23	.16	.56	.14	.10
	June 22	5:00 a.m.	1	1.15	.35	.24	1.31	.85	.66
	June 22	7:00 a.m.	2	2.95	.45	.31	.53	.22	.16
	June 22	12:00 m.	1	3.66	1.30	.90	.28	.28	.12
	June 23	1:00 p.m.	1	4.03	1.60	1.10	.10	.10	.10
4.....	June 21	11:00 p.m.	1	.38	.16	.12	.53	.10	.07
	June 22	5:00 a.m.	1	1.15	.25	.18	1.24	.63	.50
	June 22	7:00 a.m.	2	2.95	.35	.24	.50	.16	.12
	June 22	12:00 m.	1	3.66	.93	.67	.26	.11	.08
	June 23	1:00 p.m.	1	4.03	1.10	.80	.09	.09	.02
5.....	June 21	11:00 p.m.	1	.38	.19	.14	.53	.11	.07
	June 22	5:00 a.m.	1	1.15	.29	.21	1.24	.69	.58
	June 22	7:00 a.m.	2	2.95	.38	.28	.50	.17	.14
	June 22	12:00 m.	1	3.66	1.10	.80	.26	.26	.10
	June 23	1:00 p.m.	1	4.03	1.30	.95	.09	.09	.03
6.....	June 21	11:00 p.m.	1	.38	.23	.16	.64	.18	.13
	June 22	5:00 a.m.	1	1.15	.34	.23	1.51	1.04	.82
	June 22	7:00 a.m.	2	2.95	.45	.30	.60	.28	.20
	June 22	12:00 m.	1	3.66	1.30	.85	.32	.32	.14
	June 23	1:00 p.m.	1	4.03	1.60	1.10	.11	.05	.04
7.....	June 21	11:00 p.m.	1	.38	.22	.15	.64	.17	.13
	June 22	5:00 a.m.	1	1.15	.33	.23	1.51	1.02	.82
	June 22	7:00 a.m.	2	2.95	.45	.30	.60	.28	.20
	June 22	12:00 m.	1	3.66	1.30	.85	.32	.32	.14
	June 23	1:00 p.m.	1	4.03	1.50	1.10	.11	.05	.04
8.....	June 21	11:00 p.m.	1	.38	.24	.17	.61	.18	.13
	June 22	5:00 a.m.	1	1.15	.36	.26	1.44	1.00	.82
	June 22	7:00 a.m.	2	2.95	.45	.33	.57	.25	.20
	June 22	12:00 m.	1	3.66	1.30	.90	.30	.30	.13
	June 23	1:00 p.m.	1	4.03	1.60	1.20	.11	.11	.11
9.....	June 21	11:00 p.m.	1	.38	.26	.17	.74	.27	.19
	June 22	5:00 a.m.	1	1.15	.39	.26	1.75	1.39	1.13
	June 22	7:00 a.m.	2	2.95	.52	.33	.70	.39	.29
	June 23	1:00 p.m.	1	4.03	1.70	1.20	.13	.13	.13
	June 22	12:00 m.	1	3.66	1.40	.95	.37	.37	.20
10.....	June 21	11:00 p.m.	1	.38	.21	.15	.61	.16	.11
	June 22	5:00 a.m.	1	1.15	.32	.23	1.44	.94	.76
	June 22	7:00 a.m.	2	2.95	.43	.30	.57	.24	.18
	June 22	12:00 m.	1	3.66	1.20	.80	.30	.30	.12
	June 23	1:00 p.m.	1	4.03	1.50	1.00	.11	.11	.11
11.....	June 21	11:00 p.m.	1	.38	.25	.17	.74	.25	.19
	June 22	5:00 a.m.	1	1.15	.38	.24	1.75	1.37	1.08
	June 22	7:00 a.m.	2	2.95	.50	.34	.70	.38	.29
	June 22	12:00 m.	1	3.66	1.40	.95	.37	.37	.20
	June 23	1:00 p.m.	1	4.03	1.80	1.10	.13	.13	.13
12.....	June 21	11:00 p.m.	1	.38	.24	.16	.74	.23	.18
	June 22	5:00 a.m.	1	1.15	.37	.24	1.75	1.36	1.08
	June 22	7:00 a.m.	2	2.95	.50	.33	.70	.38	.29
	June 22	12:00 m.	1	3.66	1.40	.90	.37	.37	.20
	June 23	1:00 p.m.	1	4.03	1.70	1.10	.13	.13	.13
13.....	June 21	11:00 p.m.	1	.38	.26	.16	.66	.21	.14
	June 22	5:00 a.m.	1	1.15	.37	.25	1.56	1.15	.92
	June 22	7:00 a.m.	2	2.95	.50	.34	.62	.31	.24
	June 22	12:00 m.	1	3.66	1.40	.95	.33	.33	.17
	June 23	1:00 p.m.	1	4.03	1.70	1.10	.12	.12	.12
14.....	June 21	11:00 p.m.	1	.38	.25	.16	.61	.18	.13
	June 22	5:00 a.m.	1	1.15	.37	.25	1.44	1.02	.81
	June 22	7:00 a.m.	2	2.95	.49	.32	.57	.26	.19
	June 22	12:00 m.	1	3.66	1.40	.95	.30	.30	.14
	June 23	1:00 p.m.	1	4.03	1.70	1.10	.11	.11	.11

TABLE 3.--Data used to calculate runoff by subareas for the June 23, 1943, storm--Continued

Sub-area No.	Date	Time	Duration of storm (D)	Antecedent rainfall index (M)	Runoff index (B)		Excess rainfall (P)	Runoff (Q)	
					Present condition	With conservation		Present condition	With conservation
			Hours				*Inches*	*Inches*	*Inches*
15.....	June 21	11:00 p.m.	1	0.38	0.24	0.16	0.74	0.23	0.18
	June 22	5:00 a.m.	1	1.15	.35	.24	1.75	1.32	1.08
	June 22	7:00 a.m.	2	2.95	.46	.31	.70	.36	.27
	June 22	12:00 m.	1	3.66	1.30	.85	.37	.37	.19
	June 23	1:00 p.m.	1	4.03	1.60	1.10	.13	.13	.13
16.....	June 21	11:00 p.m.	1	.38	.22	.15	.74	.23	.17
	June 22	5:00 a.m.	1	1.15	.32	.22	1.75	1.26	1.02
	June 22	7:00 a.m.	2	2.95	.40	.30	.70	.33	.27
	June 22	12:00 m.	1	3.66	1.10	.80	.37	.37	.18
	June 23	1:00 p.m.	1	4.03	1.40	1.00	.13	.13	.13
17.....	June 21	11:00 p.m.	1	.38	.23	.15	.74	.23	.17
	June 22	5:00 a.m.	1	1.15	.34	.23	1.75	1.30	1.05
	June 22	7:00 a.m.	2	2.95	.45	.32	.70	.36	.28
	June 22	12:00 m.	1	3.66	1.30	.85	.37	.37	.19
	June 23	1:00 p.m.	1	4.03	1.60	1.10	.13	.13	.13
18.....	June 21	11:00 p.m.	1	.38	.24	.17	.58	.16	.12
	June 22	5:00 a.m.	1	1.15	.38	.26	1.38	.97	.77
	June 22	7:00 a.m.	2	2.95	.47	.33	.55	.24	.19
	June 22	12:00 m.	1	3.66	1.40	.95	.29	.29	.14
	June 23	1:00 p.m.	1	4.03	1.60	1.10	.10	.10	.10
19.....	June 21	11:00 p.m.	1	.38	.23	.16	.74	.24	.18
	June 22	5:00 a.m.	1	1.15	.38	.24	1.75	1.37	1.08
	June 22	7:00 a.m.	2	2.95	.47	.33	.70	.37	.29
	June 22	12:00 m.	1	3.66	1.40	.90	.37	.37	.20
	June 23	1:00 p.m.	1	4.03	1.60	1.10	.13	.13	.13
20.....	June 21	11:00 p.m.	1	.38	.24	.17	.64	.19	.14
	June 22	5:00 a.m.	1	1.15	.38	.24	1.51	1.11	.84
	June 22	7:00 a.m.	2	2.95	.46	.33	.60	.28	.22
	June 22	12:00 m.	1	3.66	1.40	.90	.32	.32	.15
	June 23	1:00 p.m.	1	4.03	1.60	1.10	.11	.11	.11
21.....	June 21	11:00 p.m.	1	.38	.22	.15	.74	.23	.17
	June 22	5:00 a.m.	1	1.15	.33	.23	1.75	1.28	1.05
	June 22	7:00 a.m.	2	2.95	.44	.30	.70	.35	.27
	June 22	12:00 m.	1	3.66	1.20	.85	.37	.37	.19
	June 23	1:00 p.m.	1	4.03	1.50	1.00	.13	.13	.13
22.....	June 21	11:00 p.m.	1	.38	.22	.16	.74	.23	.18
	June 22	5:00 a.m.	1	1.15	.34	.23	1.75	1.30	1.05
	June 22	7:00 a.m.	2	2.95	.44	.32	.70	.35	.28
	June 22	12:00 m.	1	3.66	1.20	.85	.37	.37	.19
	June 23	1:00 p.m.	1	4.03	1.50	1.05	.13	.13	.13
23.....	June 21	11:00 p.m.	1	.38	.22	.16	.74	.23	.18
	June 22	5:00 a.m.	1	1.15	.34	.23	1.75	1.30	1.05
	June 22	7:00 a.m.	2	2.95	.44	.30	.70	.35	.27
	June 22	12:00 m.	1	3.66	1.20	.85	.37	.37	.19
	June 23	1:00 p.m.	1	4.03	1.50	1.05	.13	.13	.13
24.....	June 21	11:00 p.m.	1	.38	.24	.16	.74	.24	.18
	June 22	5:00 a.m.	1	1.15	.36	.23	1.75	1.34	1.05
	June 22	7:00 a.m.	2	2.95	.49	.33	.70	.38	.29
	June 22	12:00 m.	1	3.66	1.30	.85	.37	.37	.19
	June 23	1:00 p.m.	1	4.03	1.60	1.10	.13	.13	.13
25.....	June 21	11:00 p.m.	1	.38	.21	.15	.74	.21	.17
	June 22	5:00 a.m.	1	1.15	.32	.23	1.75	1.26	1.05
	June 22	7:00 a.m.	2	2.95	.41	.30	.70	.34	.27
	June 22	12:00 m.	1	3.66	1.15	.80	.37	.37	.17
	June 23	1:00 p.m.	1	4.03	1.40	1.00	.13	.13	.13
26......	June 21	11:00 p.m.	1	.38	.20	.13	.74	.21	.14
	June 22	5:00 a.m.	1	1.15	.30	.20	1.75	1.22	.97
	June 22	7:00 a.m.	2	2.95	.42	.28	.70	.35	.25
	June 22	12:00 m.	1	3.66	1.10	.75	.37	.37	.17
	June 23	1:00 p.m.	1	4.03	1.50	.90	.13	.13	.04
27.....	June 21	11:00 p.m.	1	.38	.19	.13	.74	.21	.14
	June 22	3:00 a.m.	1	1.15	.26	.19	1.75	1.13	.95
	June 22	7:00 a.m.	2	2.95	.35	.26	.70	.30	.23
	June 22	12:00 m.	1	3.66	1.00	.70	.37	.21	.16
	June 23	1:00 p.m.	1	4.03	1.20	.80	.13	.13	.03
28.....	June 21	11:00 p.m.	1	.38	.24	.16	.74	.24	.18
	June 22	3:00 a.m.	1	1.15	.36	.25	1.75	1.34	1.11
	June 22	7:00 a.m.	2	2.95	.43	.33	.70	.35	.29
	June 22	12:00 m.	1	3.66	1.40	.90	.37	.37	.19
	June 23	1:00 p.m.	1	4.03	1.60	1.05	.13	.13	.13

TABLE 4.--Data used to calculate runoff by subareas for the June 1, 1941, storm

Sub-area No.	Date	Time	Duration of storm (D)	Antecedent rainfall index (M)	Runoff index (B)		Excess rainfall (P)	Runoff (Q)	
					Present condition	With conservation		Present condition	With conservation
			Hours				*Inches*	*Inches*	*Inches*
1.....	May 31	6:00 p.m.	4	0.1	0.037	0.030	2.10	0.35	0.28
	May 31	11:00 p.m.	3	2.1	.160	.120	2.40	1.40	1.00
	June 1	3:00 a.m.	1	4.5	1.800	1.400	.30	.30	.30
	June 1	6:00 a.m.	1	4.8	2.000	1.500	.40	.40	.40
2.....	May 31	6:00 p.m.	4	.1	.045	.032	2.4	.53	.28
	May 31	11:00 p.m.	3	2.4	.220	.150	2.7	1.97	1.63
	June 1	3:00 a.m.	1	5.1	2.000	2.000	.3	.30	.30
	June 1	6:00 a.m.	1	5.4	2.000	2.000	.4	.40	.40
3.....	May 31	6:00 p.m.	4	.1	.049	.034	2.7	.70	.51
	May 31	11:00 p.m.	3	2.7	.260	.180	3.0	2.45	2.12
	June 2	6:00 p.m.	1	5.2	2.000	2.000	.5	.50	.50
	June 1	3:00 a.m.	1	5.7	2.000	2.000	.4	.40	.40
	June 1	6:00 a.m.	1	6.1	2.000	2.000	.4	.40	.40
4.....	May 31	6:00 p.m.	4	.1	.037	.028	2.3	.41	.34
	May 31	11:00 p.m.	3	2.3	.160	.120	2.6	1.60	1.36
	June 1	3:00 a.m.	1	4.9	1.800	1.400	.3	.30	.30
	June 1	6:00 a.m.	1	5.2	2.000	1.600	.4	.40	.40
5.....	May 31	6:00 p.m.	4	.1	.040	.029	2.3	.42	.31
	May 31	11:00 p.m.	3	2.3	.180	.120	2.5	1.60	1.27
	June 1	3:00 a.m.	1	4.8	2.000	1.400	.3	.30	.30
	June 1	6:00 a.m.	1	5.1	2.000	1.600	.4	.40	.40
6.....	May 31	6:00 p.m.	4	.1	.047	.034	2.7	.69	.51
	May 31	11:00 p.m.	3	2.7	.250	.180	3.1	2.52	2.25
	June 1	3:00 a.m.	1	5.8	2.000	2.000	.4	.40	.40
	June 1	6:00 a.m.	1	6.2	2.000	2.000	.4	.40	.40
7.....	May 31	6:00 p.m.	4	.1	.045	.032	2.4	.51	.37
	May 31	11:00 p.m.	3	2.4	.210	.150	2.7	1.96	1.63
	June 1	3:00 a.m.	1	5.1	2.000	1.800	.3	.30	.30
	June 1	6:00 a.m.	1	5.4	2.000	2.000	.4	.40	.40
8.....	May 31	6:00 p.m.	4	.1	.049	.033	2.3	.51	.36
	May 31	11:00 p.m.	3	2.3	.210	.150	2.5	1.76	1.42
	June 1	3:00 a.m.	1	4.8	2.000	1.700	.3	.30	.30
	June 1	6:00 a.m.	1	5.1	2.000	2.000	.4	.40	.40
9.....	May 31	6:00 p.m.	4	.1	.053	.035	2.7	.77	.53
	May 31	11:00 p.m.	3	2.7	.280	.180	3.1	2.65	2.22
	June 1	3:00 a.m.	1	5.8	2.000	2.000	.2	.20	.20
	June 1	6:00 a.m.	1	6.0	2.000	2.000	.4	.40	.40
10.....	May 31	6:00 p.m.	4	.1	.045	.032	2.1	.41	.29
	May 31	11:00 p.m.	3	2.1	.180	.120	2.4	1.50	1.15
	June 1	3:00 a.m.	1	4.5	1.900	1.300	.3	.30	.30
	June 1	6:00 a.m.	1	4.8	2.000	1.500	.3	.30	.30
11.....	May 31	6:00 p.m.	4	.1	.053	.035	2.5	.66	.45
	May 31	11:00 p.m.	3	2.5	.260	.180	2.8	2.23	1.92
	June 1	3:00 a.m.	1	5.3	2.000	2.000	.3	.30	.30
	June 1	6:00 a.m.	1	5.6	2.000	2.000	.4	.40	.40
12.....	May 31	6:00 p.m.	4	.1	.049	.035	2.7	.70	.53
	May 31	11:00 p.m.	3	2.7	.270	.180	3.1	2.60	2.23
	June 1	3:00 a.m.	1	5.8	2.000	2.000	.2	.20	.20
	June 1	6:00 a.m.	1	6.0	2.000	2.000	.4	.40	.40
13.....	May 31	6:00 p.m.	4	.1	.050	.035	2.4	.58	.41
	May 31	11:00 p.m.	3	2.4	.240	.160	2.7	2.06	1.72
	June 1	3:00 a.m.	1	5.1	2.000	2.000	.3	.30	.30
	June 1	6:00 a.m.	1	5.4	2.000	2.000	.4	.40	.40
14.....	May 31	6:00 p.m.	4	.1	.049	.035	2.4	.56	.35
	May 31	11:00 p.m.	3	2.4	.230	.160	2.7	2.04	1.70
	June 1	3:00 a.m.	1	5.1	2.000	2.000	.3	.30	.30
	June 1	6:00 a.m.	1	5.4	2.000	2.000	.4	.40	.40

TABLE 4.--Data used to calculate runoff by subareas for the June 1, 1941, storm--Continued

Sub-area No.	Date	Time	Duration of storm (D)	Antecedent rainfall index (M)	Runoff index (B)		Excess rainfall (P)	Runoff (Q)	
					Present condition	With conservation		Present condition	With conservation
			Hours				*Inches*	*Inches*	*Inches*
15.....	May 31	6:00 p.m.	4	0.1	0.046	0.034	2.3	0.49	0.38
	May 31	11:00 p.m.	3	2.3	.220	.150	2.6	1.89	1.52
	June 1	3:00 a.m.	1	4.9	2.000	1.700	.3	.30	.30
	June 1	6:00 a.m.	1	5.2	2.000	2.000	.4	.40	.40
16.....	May 31	6:00 p.m.	4	.1	.044	.030	2.5	.56	.40
	May 31	11:00 p.m.	3	2.5	.210	.150	2.8	2.09	1.73
	June 1	3:00 a.m.	1	5.3	2.000	1.900	.3	.30	.30
	June 1	6:00 a.m.	1	5.6	2.000	2.000	.4	.40	.40
17.....	May 31	6:00 p.m.	4	.1	.046	.033	2.7	.67	.50
	May 31	11:00 p.m.	3	2.7	.240	.180	3.0	2.40	2.12
	June 1	3:00 a.m.	1	5.7	2.000	2.000	.4	.40	.40
	June 1	6:00 a.m.	1	6.1	2.000	2.000	.4	.40	.40
18.....	May 31	6:00 p.m.	4	.1	.050	.035	1.7	.30	.22
	May 31	11:00 p.m.	3	1.7	.160	.110	1.9	.96	.72
	June 1	3:00 a.m.	1	4.5	2.000	1.400	.3	.30	.30
	June 1	6:00 a.m.	1	4.8	2.000	1.800	.3	.30	.30
19.....	May 31	6:00 p.m.	4	.1	.050	.035	2.1	.44	.31
	May 31	11:00 p.m.	3	2.1	.210	.140	2.3	1.53	1.20
	June 1	3:00 a.m.	1	4.4	2.000	1.300	.3	.30	.30
	June 1	6:00 a.m.	1	4.7	2.000	1.600	.3	.30	.30
20.....	May 31	6:00 p.m.	4	.1	.051	.034	1.8	.34	.22
	May 31	11:00 p.m.	3	1.8	.170	.110	2.0	1.08	.79
	June 1	3:00 a.m.	1	3.8	1.400	1.000	.2	.20	.20
	June 1	6:00 a.m.	1	4.0	1.600	1.100	.3	.30	.30
21.....	May 31	6:00 p.m.	4	.1	.046	.032	2.4	.52	.36
	May 31	11:00 p.m.	3	2.4	2.10	.150	2.7	1.97	1.63
	June 1	3:00 a.m.	1	5.1	2.000	1.800	.3	.30	.30
	June 1	6:00 a.m.	1	5.4	2.000	2.000	.4	.40	.40
22.....	May 31	6:00 p.m.	4	.1	.045	.033	2.5	.56	.43
	May 31	11:00 p.m.	3	2.5	.230	.160	2.8	2.14	1.80
	June 1	3:00 a.m.	1	5.3	2.000	2.000	.3	.30	.30
	June 1	6:00 a.m.	1	5.6	2.000	2.000	.4	.40	.40
23.....	May 31	6:00 p.m.	4	.1	.044	.033	2.7	.65	.45
	May 31	11:00 p.m.	3	2.7	.240	.170	3.1	2.50	2.18
	June 1	3:00 a.m.	1	4.4	1.800	1.300	.3	.30	.30
	June 1	6:00 a.m.	1	4.7	2.000	1.500	.3	.30	.30
24.....	May 31	6:00 p.m.	4	.1	.050	.034	2.4	.58	.40
	May 31	11:00 p.m.	3	2.4	.240	.160	2.7	2.09	1.70
	June 1	3:00 a.m.	1	5.1	2.000	1.800	.3	.30	.30
	June 1	6:00 a.m.	1	5.4	2.000	2.000	.4	.40	.40
25.....	May 31	6:00 p.m.	4	.1	.043	.032	2.1	.38	.29
	May 31	11:00 p.m.	3	2.1	.160	.120	2.3	1.30	1.10
	June 2	6:00 p.m.	1	4.0	1.400	1.000	.5	.50	.50
	June 1	3:00 a.m.	1	4.4	1.800	1.200	.3	.30	.30
	June 1	6:00 a.m.	1	4.7	2.000	1.400	.3	.30	.30
26.....	May 31	6:00 p.m.	4	.1	.045	.030	2.3	.48	.34
	May 31	11:00 p.m.	3	2.3	.200	.130	2.5	1.72	1.33
	June 2	6:00 p.m.	1	4.3	1.500	1.100	.5	.50	.50
	June 1	3:00 a.m.	1	4.8	2.000	1.400	.3	.30	.30
	June 1	6:00 a.m.	1	5.1	2.000	1.600	.4	.40	.40
27.....	May 31	6:00 p.m.	4	.1	.039	.027	2.1	.35	.31
	May 31	11:00 p.m.	3	2.1	.160	.110	2.3	1.30	1.15
	June 1	3:00 a.m.	1	4.4	1.400	1.000	.3	.30	.30
	June 1	6:00 a.m.	1	4.7	1.600	1.200	.3	.30	.30
28.....	May 31	6:00 p.m.	4	.1	.050	.034	2.3	.54	.37
	May 31	11:00 p.m.	3	2.3	.230	.150	2.5	1.82	1.44
	June 2	6:00 p.m.	1	4.3	1.900	1.300	.5	.50	.50
	June 1	3:00 a.m.	1	4.8	2.000	1.600	.30	.30	.30
	June 1	6:00 a.m.	1	5.1	2.000	2.000	.4	.40	.40

TABLE 5.--Data used to calculate runoff by subareas for the July 12, 1951, storm

Sub-area No.	Date	Time	Duration of storm (D)	Antecedent rainfall index (M)	Runoff index (B)		Excess rainfall (P)	Runoff (Q)	
					Present condition	With conservation		Present condition	With conservation
			Hours				*Inches*	*Inches*	*Inches*
1.....	July 10	1:00 a.m.	4	0.25	0.03	0.02	6.7	2.35	1.85
	July 10	12:00 p.m.	3	6.90	1.30	.90	2.1	2.10	2.05
	July 11	4:00 a.m.	3	10.00	2.00	2.00	4.4	4.40	4.40
	July 11	12:00 m.	3	7.30	1.70	1.20	.3	.30	.30
	July 12	7:00 a.m.	7	9.00	1.20	.90	3.1	3.09	3.08
	July 12	11:00 p.m.	3	8.80	2.00	2.00	.5	.50	.50
2.....	July 10	1:00 a.m.	4	.25	.03	.02	6.3	2.45	1.72
	July 10	12:00 m.	3	6.50	1.20	.85	1.7	1.70	1.65
	July 11	4:00 a.m.	3	8.90	2.00	2.00	6.0	6.00	6.00
	July 11	12:00 n.	3	8.90	2.00	2.00	.4	.40	.40
	July 12	7:00 a.m.	7	11.30	1.50	1.00	4.3	4.30	4.30
	July 12	11:00 p.m.	3	9.60	2.00	2.00	.5	.50	.50
3.....	July 10	1:00 a.m.	4	.25	.03	.02	5.3	1.80	1.30
	July 10	12:00 p.m.	3	6.50	1.30	.85	1.8	1.80	1.75
	July 11	4:00 a.m.	3	8.90	2.00	2.00	5.7	5.70	5.70
	July 11	12:00 m.	3	8.90	2.00	2.00	.5	.50	.50
	July 12	7:00 a.m.	7	12.40	1.60	1.10	3.7	3.70	3.70
	July 12	11:00 p.m.	3	8.60	2.00	2.00	.5	.50	.50
4.....	July 10	1:00 a.m.	1	.25	.15	.08	2.3	1.25	.78
	July 10	3:00 a.m.	2	2.55	.20	.14	3.5	2.80	2.38
	July 11	1:00 a.m.	3	6.20	.85	.65	1.7	1.65	1.56
	July 11	5:00 a.m.	3	8.20	2.00	1.60	5.7	5.70	5.70
	July 11	12:00 m.	3	7.30	1.50	1.10	.3	.30	.30
	July 12	7:00 a.m.	7	8.70	1.10	.75	3.1	3.10	3.05
	July 12	11:00 p.m.	3	7.40	1.60	1.10	.5	.50	.50
5.....	July 10	1:00 a.m.	1	.25	.14	1.00	1.9	.86	.65
	July 10	3:00 a.m.	2	2.16	.18	.13	2.9	2.02	1.70
	July 11	2:00 a.m.	3	5.20	.55	.40	1.4	1.16	1.02
	July 11	6:00 a.m.	3	6.70	1.10	.80	4.1	4.10	4.10
	July 11	12:00 m.	1	6.00	2.00	2.00	.3	.30	.30
	July 12	7:00 a.m.	7	7.30	.60	.43	2.5	2.44	2.30
	July 12	11:00 p.m.	3	9.50	2.90	2.50	.5	.45	.44
6.....	July 10	2:00 a.m.	1	.40	.16	.11	.6	.12	.09
	July 10	4:00 a.m.	3	.40	.06	.03	3.7	1.36	.80
	July 11	2:00 a.m.	2	5.90	1.50	1.00	1.8	1.80	1.80
	July 11	6:00 a.m.	3	7.90	2.00	1.70	6.2	6.20	6.20
	July 11	3:00 p.m.	1	8.30	2.00	2.00	.3	.30	.30
	July 12	7:00 a.m.	7	10.50	1.60	1.00	3.1	3.10	3.10
	July 12	11:00 p.m.	3	10.70	3.30	2.60	.5	.46	.44
7.....	July 10	2:00 a.m.	1	.40	.16	.11	.6	.12	.09
	July 10	4:00 a.m.	3	1.00	.07	.05	3.7	1.65	1.22
	July 11	2:00 a.m.	2	5.90	1.40	1.00	1.0	1.00	.90
	July 11	6:00 a.m.	3	7.20	1.80	1.20	4.0	4.00	4.00
	July 11	3:00 p.m.	1	8.30	2.00	2.00	.3	.30	.30
	July 12	8:00 a.m.	5	7.00	.80	.55	2.0	1.95	1.84
	July 12	11:00 p.m.	3	8.90	3.00	2.50	1.0	.98	.97
8.....	July 10	1:00 a.m.	1	.25	.16	.11	1.4	.56	.42
	July 10	3:00 a.m.	2	1.67	.16	.11	3.2	2.20	1.80
	July 11	3:00 a.m.	2	3.90	.50	.37	1.0	.69	.58
	July 11	7:00 a.m.	2	5.10	.85	.68	3.5	3.50	3.50
	July 12	8:00 a.m.	5	6.20	.58	.43	1.8	1.64	1.50
	July 12	11:00 a.m.	3	7.50	2.10	1.40	1.0	.96	.93
9.....	July 10	3:00 a.m.	1	.40	.18	.11	.4	.06	.04
	July 10	5:00 a.m.	3	.80	.07	.05	2.3	.72	.52
	July 11	2:00 a.m.	2	3.30	.40	.28	1.5	1.13	.92
	July 11	6:00 a.m.	3	5.10	.65	.44	4.0	4.00	3.93
	July 11	3:00 p.m.	1	8.80	2.00	2.00	.4	.40	.40
	July 12	8:00 a.m.	5	7.90	1.40	.90	1.8	1.79	1.76
	July 12	11:00 p.m.	3	9.00	3.30	2.60	1.0	.98	.97
10.....	July 10	1:00 a.m.	1	.25	.14	.10	1.3	.44	.32
	July 10	3:00 a.m.	2	1.60	.14	.10	2.5	1.39	1.12
	July 11	4:00 a.m.	2	3.90	.49	.34	4.5	4.50	4.34
	July 12	8:00 a.m.	5	6.00	.53	.35	1.8	1.61	1.38
	July 12	11:00 p.m.	3	6.80	1.30	.90	1.0	.92	.88
11.....	July 10	3:00 a.m.	1	.40	.18	.12	.4	.06	.05
	July 10	5:00 a.m.	3	.80	.07	.05	2.6	.95	.68
	July 11	3:00 a.m.	5	3.50	.17	.11	4.0	3.16	2.55
	July 12	9:00 a.m.	5	6.10	.65	.43	1.7	1.56	1.39
	July 12	11:00 p.m.	3	6.30	1.30	.88	1.0	.92	.87
12.....	July 10	3:00 a.m.	1	.40	.17	.11	.4	.05	.04
	July 10	5:00 a.m.	3	.80	.07	.05	2.4	.76	.52
	July 11	3:00 a.m.	5	3.30	.14	.10	5.0	4.00	3.34
	July 12	9:00 a.m.	5	7.00	.88	.58	1.7	1.64	1.53
	July 12	11:00 p.m.	3	8.30	2.70	2.10	1.0	.98	.97

TABLE 5.--Data used to calculate runoff by subareas for the July 12, 1951, storm--Continued

Sub-area No.	Date	Time	Duration of storm (D)	Antecedent rainfall index (M)	Runoff index (B)		Excess rainfall (P)	Runoff (Q)	
					Present condition	With conservation		Present condition	With conservation
			Hours				Inches	Inches	Inches
13.....	July 9	12:00 p.m.	1	0.23	0.16	0.11	2.3	1.30	1.04
	July 10	2:00 a.m.	3	2.97	.22	.15	1.2	.54	.40
	July 11	4:00 a.m.	2	3.60	.50	.33	4.2	4.10	4.02
	July 12	10:00 a.m.	1	5.00	2.00	1.30	1.0	1.00	1.00
	July 12	11:00 p.m.	2	6.50	2.00	1.50	1.0	1.00	1.00
14.....	July 9	12:00 p.m.	1	.23	.16	.110	2.5	1.50	1.18
	July 10	2:00 a.m.	3	2.97	.20	.140	[illegible]	.51	.38
	July 11	5:00 a.m.	2	3.80	.50	.350	2.6	2.46	2.25
	July 12	10:00 a.m.	1	3.90	1.10	.740	1.0	1.00	.82
	July 12	11:00 p.m.	2	5.60	1.40	.900	1.0	1.00	.88
15.....	July 9	12:00 p.m.	1	.23	.15	.100	2.3	1.50	.90
	July 10	2:00 a.m.	3	2.97	.20	.140	1.1	.44	.32
	July 11	5:00 a.m.	2	3.50	.40	.280	2.9	2.71	2.46
	July 12	10:00 a.m.	1	4.30	1.20	.850	.8	.80	.64
	July 12	11:00 p.m.	2	5.60	1.20	.850	1.0	1.00	.84
16.....	July 9	12:00 p.m.	1	.23	.14	.090	2.1	1.04	.74
	July 10	2:00 a.m.	3	2.97	.18	.120	1.0	.35	.24
	July 11	5:00 a.m.	2	3.30	.35	.230	3.4	3.17	2.81
	July 12	10:00 a.m.	1	4.40	1.20	.850	.8	.80	.64
	July 12	11:00 p.m.	2	5.70	1.20	.850	1.0	1.00	.87
17.....	July 9	12:00 p.m.	1	.23	.15	.100	2.1	1.08	.80
	July 10	2:00 a.m.	3	2.97	.20	.140	1.0	.36	.27
	July 11	5:00 a.m.	2	3.20	.35	.240	3.4	3.16	2.84
	July 12	10:00 a.m.	1	4.40	1.30	.900	.8	.80	.65
	July 12	11:00 p.m.	2	5.70	1.30	.900	1.0	1.00	.88
18.....	July 9	12:00 p.m.	1	.23	.16	.110	2.5	1.50	1.20
	July 10	2:00 a.m.	3	2.97	.22	.140	1.2	.54	.38
	July 11	6:00 a.m.	2	3.80	.52	.350	3.0	3.00	2.70
	July 12	10:00 a.m.	1	3.70	1.00	.690	[illegible]	.79	.68
	July 12	8:00 p.m.	2	5.10	1.00	.690	.7	.57	.47
19.....	July 9	12:00 p.m.	1	.23	.16	.100	2.2	1.20	.88
	July 10	2:00 a.m.	3	2.97	.22	.140	1.0	.40	.27
	July 11	6:00 a.m.	2	3.40	.42	.280	2.4	2.17	1.86
	July 12	10:00 a.m.	1	3.70	1.00	.650	[illegible]	.67	.56
	July 12	8:00 p.m.	1	4.90	1.90	1.200	.5	.50	.50
20.....	July 9	12:00 p.m.	1	.23	.16	.100	2.0	1.05	.74
	July 10	2:00 a.m.	3	2.97	.22	.140	[illegible]	.32	.22
	July 11	7:00 a.m.	2	3.10	.35	.240	1.9	1.49	1.22
	July 12	10:00 a.m.	1	3.10	.70	.470	.5	.28	.18
	July 12	8:00 p.m.	1	4.10	1.20	.800	.7	.70	.51
21.....	July 9	6:00 p.m.	1	.23	.14	.095	2.2	1.10	.85
	July 10	2:00 a.m.	3	2.97	.19	.140	1.0	.35	.27
	July 11	6:00 a.m.	2	3.40	.37	.260	2.6	2.29	2.00
	July 12	10:00 a.m.	1	3.90	.95	.660	.6	.43	.36
	July 12	8:00 p.m.	1	5.00	1.70	1.100	.5	.50	.50
22.....	July 9	6:00 p.m.	1	.23	.15	.10	2.2	1.15	.88
	July 10	2:00 a.m.	3	2.97	.19	.14	1.0	.35	.27
	July 11	7:00 a.m.	2	3.40	.40	.26	2.8	2.58	2.23
	July 21	10:00 a.m.	1	4.10	1.10	.65	.5	.35	.26
	July 12	8:00 p.m.	1	5.10	1.90	1.20	.5	.50	.50
23.....	July 9	6:00 p.m.	1	.23	.15	.096	2.1	1.07	.75
	July 10	2:00 a.m.	3	2.97	.19	.130	1.0	.35	.26
	July 11	7:00 a.m.	2	3.30	.35	.260	1.9	1.49	1.29
	July 12	10:00 a.m.	1	3.20	.70	.480	.3	.11	.08
	July 12	8:00 p.m.	1	3.80	.90	.650	.7	.54	.45
24.....	July 9	6:00 p.m.	1	.23	.16	.100	2.2	1.20	.86
	July 10	2:00 a.m.	3	2.97	.22	.150	1.0	.40	.29
	July 11	8:00 a.m.	2	3.40	.44	.28	2.2	1.97	1.65
	July 12	10:00 a.m.	1	3.50	.90	.55	.4	.22	.16
	July 12	8:00 p.m.	1	4.40	1.40	.89	.5	.50	.32
25.....	July 9	6:00 p.m.	1	.23	.14	.095	2.1	1.03	.75
	July 10	2:00 a.m.	3	2.97	.18	.13	1.0	.34	.26
	July 11	8:00 a.m.	2	3.30	.35	.24	1.9	1.49	1.23
	July 12	10:00 a.m.	1	3.20	.65	.44	.4	.18	.13
	July 12	8:00 p.m.	1	4.00	1.00	.70	.7	.57	.47
26.....	July 9	6:00 p.m.	1	.23	.14	.09	2.2	1.10	.80
	July 10	2:00 a.m.	3	2.97	.18	.13	1.0	.34	.26
	July 11	8:00 a.m.	2	3.40	.36	.26	2.0	1.60	1.39
	July 12	10:00 a.m.	1	3.30	.65	.44	.4	.18	.13
	July 12	8:00 p.m.	1	4.10	.95	.69	.5	.32	.27
27.....	July 9	6:00 p.m.	1	.23	.12	.08	2.1	.91	.67
	July 10	2:00 a.m.	3	2.97	.16	.12	1.0	1.30	.24
	July 11	9:00 a.m.	2	3.40	.32	.22	1.7	1.20	.98
	July 12	10:00 a.m.	1	3.00	.48	.34	.2	.04	.03
	July 12	8:00 p.m.	2	3.40	.32	.22	1.0	.52	.40
28.....	July 9	6:00 p.m.	1	.23	.16	.11	2.2	1.20	.95
	July 10	2:00 a.m.	3	2.97	.22	.15	1.2	.40	.29
	July 11	9:00 a.m.	2	3.30	.40	.28	1.7	1.34	1.12
	July 12	10:00 a.m.	1	3.30	.70	.50	.2	.06	.05
	July 12	8:00 p.m.	2	3.80	.50	.35	.8	.49	.38

TABLE 6.--Cover-practice indices

Subarea No.	Average cover practice index	
	Present condition	Future condition
1	8.3	6.3
2	9.6	6.8
3	10.5	7.3
4	8.2	6.1
5	8.7	6.4
6	10.3	7.2
7	9.8	6.9
8	10.1	7.2
9	11.2	7.6
10	9.8	7.0
11	11.9	8.0
12	10.8	7.5
13	10.8	7.4
14	10.5	7.3
15	10.3	7.2
16	9.4	6.7
17	10.2	7.1
18	10.5	7.4
19	10.9	7.5
20	11.0	7.5
21	9.8	6.9
22	9.8	7.1
23	9.7	6.9
24	11.1	7.5
25	9.3	6.7
26	9.9	6.9
27	8.8	6.4
28	11.1	7.6

TABLE 7.--Weighted

Land capability subclasses average depth subsoil permeability		I Deep moderately slow	II el Deep moderately slow	II s deep very slow	III el moderately deep slow	III sl deep moderately slow	IV el moderately deep slow	IV s2 moderately deep very slow
Soil index		0.25	0.25	0.05	0.10	0.25	0.10	0.05
Subarea No.	Area-Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres
1	18,536	41	65	36	4,861	133	3,168	89
2	18,648	390	124	97	5,405	142	3,106	97
3	16,640	761	208	152	5,239	130	2,584	94
4	10,368	122	94	25	2,569	69	1,609	46
5	20,480	308	158	75	5,453	145	3,295	99
6	22,208	891	249	183	6,861	172	3,504	123
7	20,928	676	211	141	6,191	157	3,320	110
8	16,640	566	147	126	5,147	131	2,723	93
9	16,512	892	217	178	5,489	134	2,573	98
10	19,968	637	185	140	6,010	153	3,228	108
11	13,376	937	223	178	4,690	110	2,001	82
12	17,728	843	210	173	5,751	142	2,804	103
13	17,536	803	191	168	5,731	142	2,823	103
14	15,040	611	151	130	4,800	120	2,438	86
15	17,792	752	211	152	5,521	137	2,782	99
16	14,912	449	167	90	4,212	107	2,304	76
17	22,528	933	269	188	6,925	172	3,510	124
18	19,840	822	201	176	6,355	159	3,213	113
19	17,664	934	234	185	5,811	142	2,744	103
20	15,616	866	224	168	5,117	124	2,380	91
21	8,256	321	105	62	2,437	61	1,260	44
22	23,168	806	252	166	6,894	174	3,645	123
23	17,728	583	185	121	5,233	133	2,801	94
24	12,928	792	214	148	4,241	101	1,901	75
25	17,280	438	156	96	4,922	127	2,767	89
26	15,872	763	263	134	4,634	113	2,259	82
27	15,360	476	216	82	4,050	103	2,224	71
28	14,528	858	221	165	4,817	116	2,190	86

soil indices

IV w deep slow	VI el moderately deep slow	VI els shallow to mod. deep very slow	VI w deep moderate	VII s very shallow very slow	VII w deep moderate	Cumulative sum of products of subclass area index	Weighted subarea (soil index S)
0.10	0.10	0.05	0.60	0.05	0.60		
Acres	Acres	Acres	Acres	Acres	Acres		
72	2,458	7,252	0	361	0	1,502.55	0.081
93	2,342	6,527	0	325	0	1,610.90	.086
156	1,877	4,795	96	324	224	1,720.60	.103
116	1,248	3,678	324	132	336	1,215.50	.117
167	2,526	7,266	148	495	345	1,989.40	.097
185	2,568	6,710	102	424	237	2,215.20	.100
174	2,469	6,666	115	432	266	2,072.45	.099
96	2,009	5,336	0	266	0	1,499.55	.090
140	1,837	4,502	54	271	127	1,675.70	.100
137	2,396	6,442	50	366	116	1,873.00	.110
143	1,388	3,136	79	224	185	1,479.10	.111
136	2,026	5,104	44	291	101	1,741.00	.098
112	2,042	5,165	0	256	0	1,639.40	.093
92	1,780	4,603	0	229	0	1,383.90	.092
159	2,033	5,272	98	348	228	1,813.65	.102
157	1,728	4,741	153	372	356	1,590.20	.107
208	2,572	6,699	141	458	329	2,320.45	.103
123	2,342	6,036	0	300	0	1,830.05	.092
156	1,965	4,846	72	304	168	1,811.00	.103
159	1,698	4,154	102	296	237	1,677.75	.107
90	929	2,467	85	198	197	901.10	.109
205	2,701	7,231	145	488	338	2,342.70	.101
153	2,083	5,611	107	375	249	1,775.90	.100
162	1,346	3,213	137	280	318	1,500.55	.116
138	2,083	5,767	97	374	226	1,681.35	.097
248	1,651	4,271	295	474	685	2,000.00	.126
235	1,682	4,693	307	506	715	1,898.65	.124
156	1,554	3,736	106	278	245	1,594.30	.110

TABLE 8.--Drainage area of subareas

Subarea No.	Total area		Reservoired area		Unreservoired area	
	Acres	*Square miles*	*Acres*	*Square miles*	*Acres*	*Square miles*
1	18,536	28.9	17,051	26.6	1,485	2.3
2	18,648	29.1	10,097	15.8	8,551	13.3
3	16,640	26.0	4,312	6.7	12,328	19.3
4	10,368	16.2	4,597	7.2	5,771	9.0
5	20,480	32.0	12,168	19.0	8,312	13.0
6A	9,664	15.1	2,529	4.0	7,135	11.1
6B	12,544	19.6	3,693	5.8	8,851	13.8
7	20,928	32.7	6,470	10.1	14,458	22.6
8	16,640	26.0	6,251	9.8	10,389	16.2
9	16,512	25.8	9,256	14.5	7,256	11.3
10	19,968	31.2	7,692	12.1	12,276	19.1
11	13,376	20.9	6,858	10.7	6,518	10.2
12	17,728	27.7	14,343	22.4	3,385	5.3
13	17,536	27.4	8,819	13.8	8,717	13.6
14	15,040	23.5	10,779	16.8	4,261	6.7
15	17,792	27.8	10,119	15.8	7,673	12.0
16A	9,070	14.2	6,991	10.9	2,079	3.3
16B	5,842	9.1	1,222	1.9	4,620	7.3
17A	16,256	25.4	10,347	16.2	5,909	9.2
17B	6,272	9.8	3,104	4.9	3,168	4.9
18	19,840	31.0	11,752	18.4	8,088	12.6
19	17,664	27.6	8,303	12.9	9,361	14.7
20	15,616	24.4	6,406	10.0	9,210	14.4
21	8,256	12.9	4,553	7.1	3,703	5.8
22	23,168	36.2	10,593	16.6	12,575	19.6
23	17,728	27.7	11,998	18.7	5,730	9.0
24	12,928	20.2	4,923	7.7	8,005	12.5
25	17,280	27.0	11,057	17.3	6,223	9.7
26A	5,112	8.0	2,442	3.8	2,670	4.2
26B	10,760	16.8	3,272	5.1	7,488	11.7
27	15,360	24.0	12,521	19.6	2,839	4.4
28	14,528	22.7	10,404	16.3	4,124	6.4
Total	478,080	747.0	254,922	398.5	223,158	348.5

TABLE 9.--Runoff and triangular hydrograph characteristics (sample worksheet) subarea No. 5, at head of routing reach 1C, April 13, 1947, storm

Symbol	Name	Unit	April 12 10 p.m.	April 13 9 a.m.	April 13 1 p.m.
S	Soil index		0.097	0.097	0.097
D	Duration of storm	hours	2.0	2.0	1.0
C_p	Cover-practice index (present condition)		8.7	8.7	8.7
C_c	Cover-practice index (with land treatment)		6.4	6.4	6.4
M	Antecedent rainfall index		1.37	2.36	2.86
T	Seasonal index		.9	.9	.9
B_p	Runoff index (present condition)		.29	,50	1.2
B_c	Runoff index (with land treatment)		.22	.38	.95
P	Excess precipitation	inches	1.1	.5	.5
Q_p	Volume of runoff (present condition)	inches	.57	.22	.45
Q_c	Volume of runoff (with land treatment)	inches	.47	.17	.32
A	Total area in square miles		32.0	32.0	32.0
T_c	Travel time	hours	3.0	3.0	3.0
T_l	Lag time	hours	1.8	1.8	1.8
T_p	Time to peak	hours	2.8	2.8	2.3
R	Peak discharge per inch of runoff	c. f. s.	5,400.0	5,400.0	6,500.0
T_r	Recession time	hours	4.7	4.7	3.8
q_p	Peak discharge (present condition)	c.f. s.	3,078.0	1,188.0	2,925.0
q_c	Peak discharge (with land treatment)	c. f. s.	2,538.0	918.0	2,080.0
A_1	Uncontrolled area in square miles		13.0	13.0	13.0
T_c	Travel time	hours	2.9	2.9	2.9
T_l	Lag time	hours	1.8	1.8	1.8
T_p	Time to peak	hours	2.8	2.8	2.3
R	Peak, discharge per inch of runoff	c. f. s.	2,200.0	2,200.0	2,700.0
q_p	Peak discharge (present condition)	c. f. s.	1,254.0	484.0	1,215.0
q_c	Peak discharge (with land treatment)	c. f. s.	1,034.0	374.0	864.0

TABLE 10.—Emergency spillway discharge computation (worksheet--combined with graphical solution of figure 32. Present condition, subarea 9)

(1) Rainfall burst number	(2) Weighted reservoir storage	(3) Spillway discharge from previous bursts	(4) Total volume (col. 2 + col. 3)	(5) Total volume (col. 4 + pipe discharge added graphically on fig. 32)	(6) Total inflow to end of burst (sum of inflow hydrographs)	(7) Volume of spillway discharge (col. 6 -5)	(8) Weighted spillway storage volume for 3.5-ft. depth	(9) Ratio of spillway storage to spillway discharge (col. 8 ÷ col. 7)
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	
6..........	5.6	0	5.6	6.75	8.10	1.35	1.61	1.19
7..........	5.6	1.35	6.95	8.45	9.08	.63	1.61	2.55

(10) Ratio of outflow to inflow from fig. 31	(11) Peak inflow discharge	(12) Peak spillway discharge (col. 10 x col. 11)	(13) Time to peak computed graphically from fig. 32	(14) Volume of spillway outflow to time of peak $\left(\frac{\text{col. 12 x col. 13}}{\text{2 x 9,356 acres}}\right)$	(15) Volume of spillway outflow after time of peak (col. 7 - col. 14)	(16) Time from peak to end of spillway discharge $\left(\frac{\text{9,356 acres x col. 15 x 2}}{\text{col. 12}}\right)$
	C. f. s.	*C. f. s.*	*Hours*	*Inches*	*Inches*	*Hours*
0.3..........	2,685	805	8.5	0.37	0.98	22.7
1.3..........	1,862	558	8.4	.25	.38	12.7

TABLE 11--Area inundated and storage volume calculations (worksheet)

(Dam No. 15-5--drainage area 2,200 acres)

Assumed elevation	Depth	Area	Average area increment	Depth increment	Storage increment	Total storage	
Feet	*Feet*	*Acres*	*Acres*	*Feet*	*Acre-feet*	*Acre-feet*	*Inches*
970	0	0			0	0	0
			1.7	10			
980	10	3.4			17	17	.09
			9.8	10			
990	20	16.3			98	115	.63
			24.2	10			
1,000	30	32.2			242	357	1.95
			48.4	10			
1,010	40	64.6			484	841	4.59
			101.9	10			
1,020	50	139.2			1,019	1,860	10.1

TABLE 12.--Area inundated by reservoirs

Subarea No.	Site No.	Design storage	1947 storm runoff	Area inundated		
				Sediment pool[1]	1947 storm	For design storage
		Inches	*Inches*	*Acres*	*Acres*	*Acres*
1..................	1................	4	1.14	1	15	27
	2................	5	1.14	9	18	75
	2A...............	5	1.14	4	16	62
	2B...............	4	1.14	2	8	21
	3................	6	1.14	32	96	256
2..................	3................	6	1.02	17	43	144
	4................	6	1.02	14	42	146
	5................	4	1.02	1	4	10
	9................	4	1.02	1	8	18
3..................	1................	5	.87	11	28	114
	2................	4	.87	4	14	47
	4................	4	.87	2	7	22
	6................	4	.87	1	2	36
4..................	1................	6	.89	3	23	96
	3................	4	.89	4	15	39
5..................	1................	6	.97	14	44	134
	2................	4	.97	.5	5	19
	9................	4	.97	1	4	32
	11...............	6	.97	10	60	216
6..................	1................	5	.88	3	26	92
	3................	4	.88	2	7	31
	4................	6	.88	8	22	112
	9................	4	.88	4	10	28
7..................	2................	4	1.00	4	10	27
	9................	4	1.00	2	8	42
	7................	5	1.00	3	26	72
	8................	5	1.00	5	25	84
8..................	1A...............	4	1.21	9	24	60
	1B...............	6	1.21	16	46	190
	2................	4	1.21	4	10	19
	3................	4	1.21	3	11	28
9..................	1................	6	.81	4	20	98
	2................	6	.81	5	22	156
	3................	4	.81	5	12	40
	3A	4	.81	6	8	30
10.................	1................	6	1.32	16	48	156
	3................	4	1.32	2	8	20
	4................	4	1.32	5	21	52
	5................	4	1.32	1	12	23
	7................	4	1.32	2	11	25
	9................	4	1.32	1	10	30
11.................	2................	6	.97	10	32	126
	3................	6	.97	4	25	85
	5................	4	.97	9	19	58
12.................	1................	6	.94	8	48	150
	2................	4	.94	4	10	25
	3................	6	.94	4	29	162
	4................	4	.94	3	9	37
	5................	4	.94	1	7	20
13.................	1................	5	.94	3	16	74
	2................	6	.94	6	30	135
	3................	4	.94	7	14	50
	6................	4	.94	.5	10	45
	7................	4	.94	4	10	26
	8................	4	.94	2	10	29
14.................	KB...............	6	1.49	16	80	224
	K136.............	5	1.49	15	50	120
	K138.............	5	1.49	12	28	74
	K112.............	4	1.49	4	18	36
15.................	1................	5	1.35	7	22	74
	2................	4	1.35	3	11	21
	2A...............	4	1.35	1	7	13
	3................	4	1.35	2	8	15
	4................	4	1.35	1	12	32
	5................	5	1.35			
	6................	4	1.35	2	20	41
	7................	4	1.35	5	23	61
	8................	4	1.35	1	5	12
	9................	4	1.35	4	16	37

TABLE 12.—Area inundated by reservoirs—Continued

Subarea No.	Site No.	Design storage	1947 storm runoff	Area inundated		
				Sediment pool[1]	1947 storm	For design storage
		Inches	*Inches*	*Acres*	*Acres*	*Acres*
16	1	6	1.27	1	34	118
	2	5	1.27	4	21	76
	3	4	1.27	2	15	31
	4	4	1.27	5	20	53
	5	4	1.27	1	6	15
17	1	6	1.32	1	32	150
	2	5	1.32	2	28	57
	3	4	1.32	4	13	38
	4	6	1.32	6	46	140
	5	5	1.32	10	34	92
	6	4	1.32	3	10	23
18	5	4	1.67	2	26	56
	6	4	1.67	4	17	37
	7	6	1.67	10	130	310
19	K33	4	1.46	5	18	37
	K38	4	1.46	4	13	28
	K45	5	1.46	7	21	43
	K53	5	1.46	16	52	136
	K56	4	1.46	4	14	33
	K61	4	1.46	13	38	83
	K72	4	1.46	5	15	29
	K91	4	1.46	6	21	38
20	1	6	1.64	6	38	148
	2	4	1.64	1	7	23
	3	4	1.64	1	6	22
	4	4	1.64	4	15	33
	6	4	1.64	1	12	24
	7	4	1.64	2	7	17
21	1	5	1.36	4	28	58
	2	4	1.36	1	6	15
	3	4	1.36	3	15	32
	5	4	1.36	1	3	13
	6	4	1.36	1	10	32
22	1	4	.90	2	7	52
	2	4	.90	3	7	22
	3	6	.90	6	39	207
	4	5	.90	5	14	73
	5A	4	.90	2	6	22
	5B	4	.90	2	10	45
	5C	4	.90	2	15	56
	6	4	.90	1	3	23
23	K1	5	.99	9	21	68
	K11	6	.99	12	30	112
	K28	4	.99	2	7	16
	3	6	.99	6	22	80
	4	5	.99	5	13	40
	5	6	.99	6	20	68
24	1A	4	.28	2	2	19
	1B	5	.28	4	4	104
	1C	4	.28	1	1	27
	3	4	.28	1	1	32
	6	4	.28	2	2	30
	7	4	.28	1	1	14
25	1	4	.99	1	14	48
	3	4	.99	5	15	50
	4	5	.99	6	27	70
	5	4	.99	4	13	31
	6	6	.99	4	21	99
	7	4	.99	2	10	31
	8	5	.99	5	24	81
	9	4	.99	.2	1	3
	10	4	.99	1	4	11
	11	4	.99	1	3	7
26	2	6	.97	4	17	122
	3	4	.97	2	5	20
	4	4	.97	2	11	43
	5	4	.97	7	19	51
27	11	6	.95	23	130	340
28	2	6	.28	12	12	170
	3	4	.28	1	1	12
	4	4	.28	1	1	48
	5	6	.28	14	14	114
Total				689.2	2,756	9,212

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[1] Sediment storage volume allowance equivalent to 0.3 inches from the watershed.

TABLE 13—Fill-volume computations, site 15-5

Station	Length of section	Height of fill	Fill per lineal foot (from volume table)	Average fill per lineal foot	Volume of fill in section
	Feet	*Feet*	*Cubic yards*	*Cubic yards*	*Cubic yards*
0		7	8		
	100			14	1,400
100		12	20		
	150			65	9,750
250		32	111		
	70			194	13,580
320		52	277		
	40			277	11,080
360		52	277		
	60			231	13,860
420		42	185		
	150			165	24,750
570		37	146		
	210			128	26,880
780		32	111		
	100			96	9,600
880		27	82		
	70			69	4,830
950		22	56		
	320			46	14,720
1,270		17	36		
	230			28	6,440
1,500		12	20		
	320			10	3,200
1,820		0	0		
Total					140,090

TABLE 14.—Retarding structure data

Subarea No.	Site No.	Drainage area above structure		Storage volume	Fill volume	Fill volume per acre-foot of storage
		Acres	*Square miles*	*Acre-feet*	*Cubic yards*	*Cubic yards*
1	1	1,080	1.7	360	74,860	208
	2	2,257	3.5	939	129,535	138
	2A	1,963	3.1	816	83,240	102
	2B	564	.9	188	40,309	214
	3	11,187	17.5	5,637	298,763	53
2	3	5,260	8.2	2,632	302,646	115
	4	3,804	5.9	1,891	104,004	55
	5	329	.5	110	26,580	242
	9	704	1.1	235	70,270	299
3	1	2,437	3.8	1,018	138,461	136
	2	937	1.5	302	32,717	105
	4	469	.7	156	37,786	242
	6	469	.7	235	39,290	167
4	1	3,320	5.2	1,660	247,360	149
	3	1,277	2.0	427	65,711	154
5	1	4,006	6.3	1,991	159,281	80
	2	751	1.2	250	65,495	262
	9	901	1.4	300	65,750	219
	11	6,510	10.2	3,283	167,440	51
6	1	2,175	3.4	1,088	119,720	110
	3	759	1.2	253	41,510	164
	4	2,529	4.0	1,266	100,005	79
	9	759	1.2	253	33,910	134
7	2	882	1.4	230	41,440	180
	9	980	1.5	327	52,320	160
	7	2,108	3.3	877	68,420	78
	8	2,500	3.9	1,042	110,430	106
8	1A	1,378	2.2	461	39,646	86
	1B	3,052	4.8	1,528	125,290	82
	2	738	1.2	246	47,737	194
	3	1,083	1.7	360	69,570	193
9	1	3,209	5.0	1,608	128,640	80
	2	4,419	6.9	2,219	86,570	39
	3	930	1.5	309	36,760	119
	3A	698	1.1	233	38,249	164
10	1	3,000	4.7	1,493	77,640	52
	3	599	.9	200	68,227	341
	4	1,398	2.2	465	58,500	126
	5	749	1.2	250	64,728	259
	7	998	1.6	333	92,370	277
	9	948	1.5	315	56,480	179
11	2	2,821	4.4	1,430	63,571	45
	3	2,821	4.4	1,399	83,973	60
	5	1,216	1.9	405	29,505	73
12	1	5,909	9.2	2,938	235,038	80
	2	905	1.4	302	49,370	163
	3	5,623	8.8	2,810	177,020	63
	4	953	1.5	317	46,353	146
	5	953	1.5	319	38,230	120
13	1	1,754	2.7	728	33,480	46
	2	3,407	5.3	1,713	135,365	79
	3	902	1.4	300	41,990	140
	6	1,002	1.6	334	60,746	182
	7	752	1.2	251	41,185	164
	8	1,002	1.6	335	46,580	139
14	K Site B	5,632	8.8	2,802	112,080	40
	K 112	832	1.3	277	52,850	191
	K 136	2,304	3.6	957	89,925	94
	K 138	1,792	2.8	748	77,840	104

TABLE 14.--Retarding structure data--Continued

Subarea No.	Site No.	Drainage area above structure		Storage volume	Fill volume	Fill volume per acre-foot of storage
		Acres	*Square miles*	*Acre-feet*	*Cubic yards*	*Cubic yards*
15	1	1,711	2.7	712	50,530	71
	2	733	1.1	244	58,910	241
	2A	391	.6	130	30,810	237
	3	538	.8	179	36,360	203
	4	880	1.4	293	66,760	228
	5	2,200	3.4	920	140,090	153
	6	1,466	2.3	487	42,330	87
	7	978	1.5	326	83,785	257
	8	391	.6	130	37,353	287
	9	831	1.3	277	20,770	75
16	1	2,934	4.6	1,463	144,820	99
	2	2,102	3.3	876	118,257	135
	3	1,222	1.9	406	52,340	129
	4	1,222	1.9	408	35,075	86
	5	733	1.1	243	34,760	142
17	1	4,233	6.6	2,121	173,920	82
	2	1,693	2.6	701	55,405	79
	3	894	1.4	298	44,680	150
	4	3,527	5.5	1,778	103,095	58
	5	2,210	3.5	920	61,620	67
	6	894	1.4	298	50,440	169
18	5	1,272	2.0	425	44,220	104
	6	814	1.3	272	28,515	105
	7	9,666	15,1	4,839	304,850	63
19	K-33	1,024	1.6	341	63,430	186
	K-38	1,024	1.6	342	64,585	189
	K-45	1,344	2.1	448	58,220	130
	K-53	1,792	2.8	742	38,570	52
	K-56	704	1.1	235	42,030	179
	K-61	1,152	1.8	385	28,855	75
	K-72	640	1.0	214	25,230	118
	K-91	896	1.4	300	33,910	113
20	1	3,754	5.9	1,871	72,980	39
	2	400	.6	133	34,040	256
	3	400	.6	133	27,570	207
	4	1,001	1.6	334	49,450	148
	6	501	.8	167	37,980	227
	7	350	.5	117	22,410	192
21	1	1,601	2.5	667	42,025	63
	2	500	.8	167	40,685	244
	3	1,201	1.9	400	38,770	97
	5	500	.8	167	25,250	151
	6	751	1.2	250	21,515	86
22	1	890	1.4	297	31,460	106
	2	594	.9	1,198	34,465	174
	3	4,010	6.3	2,024	97,170	48
	4	1,980	3.1	824	63,430	77
	5A	396	.6	132	30,150	228
	5B	990	1.5	329	49,720	151
	5C	1,238	1.9	412	38,730	94
	6	495	.8	165	30,400	184
23	K 1	2,176	3.4	908	96,200	106
	K11	2,560	4.0	1,274	108,330	85
	K28	448	.7	149	44,325	297
	3	2,716	4.2	1,356	181,755	134
	4	1,728	2.7	719	114,374	159
	5	2,518	3.9	1,255	141,810	113
24	1A	448	.7	149	26,870	180
	1B	1,939	3.0	586	66,510	113
	1C	547	.9	182	42,940	236
	3	696	1.1	232	29,030	125
	6	895	1.4	120	35,720	298
	7	398	.6	133	30,255	227
25	1	1,101	1.7	334	65,429	196
	3	909	1.4	302	32,900	109
	4	1,915	3.0	801	72,900	91
	5	718	1.1	239	71,480	299
	6	2,872	4.5	1,430	90,095	63
	7	814	1.3	271	56,560	209
	8	2,154	3.4	902	70,350	78
	9	96	.2	32	18,445	576
	10	239	.4	80	27,010	338
	11	239	.4	80	36,695	459
26	2	2,881	4.5	1,450	113,070	78
	3	391	.6	219	28,520	130
	4	1,221	1.9	406	38,950	96
	5	1,221	1.9	407	51,695	127
27	11	12,521	19.6	6,357	165,290	26
28	2	5,108	8.0	2,579	121,210	47
	3	469	.7	156	45,408	291
	4	1,078	1.7	361	21,680	60
	5	3,749	5.9	1,866	149,250	80
Total			399.0	112,026	10,280,542	

TABLE 15.--Average slope and adjusted "n" values

Cross section No.	Location river mile	Average slope in feet per mile		Adjusted "n" value	
		Channel	Overbank	Channel	Overbank
	Main Stem				
RM 268.0....	268.0	1.68	3.05	0.019	0.027
RM 270.3....	270.3	1.84	3.18	.028	.040
RO-V-56.....	273.4	2.00	3.43	.078	.111
RM 275.3....	275.3	2.12	4.00	.050	.080
RM 279.0....	279.0	4.93	3.17	.040	.064
RM 281.9....	281.9	5.05	3.00	.030	.077
RO-V-58.....	283.0	2.86	2.53	.052	.071
RM 287.5....	287.5	2.39	2.41	.074	.098
RM 290.5....	290.5	1.56	2.87	.054	.074
RO-V-61.....	297.2	3.43	3.80	.024	.032
RM 300.8....	300.8	3.30	4.94	.023	.030
RO-V-62.....	303.7	4.17	5.85	.032	.042
RO-V-63.....	306.8	4.53	6.54	.034	.044
RO-V-64.....	311.3	4.74	6.16	.040	.047
RO-V-65.....	313.9	6.27	6.11	.039	.050
RO-V-66.....	317.3	4.62	6.77	.065	.085
RO-V-67.....	322.0	4.19	7.51	.048	.062
RO-V-68.....	330.0	5.92	8.44	.045	.058
D- 1........	334.7	6.14	8.44	.040	.051
D- 2........	339.3	7.09	9.67	.069	.086
D- 3........	342.2	13.48	14.47	.090	.111
D- 4........	343.9	16.58	17.47	.057	.070
D- 5........	345.2	15.22	18.41	.032	.039
D- 6........	347.5	15.00	18.86	.042	.052
	Walnut Creek				
A- 1........	2.7	4.53	1.11	.043	.058
A- 2........	4.1	2.40	2.49	.030	.045
A- 3........	5.1	5.04	6.01	.044	.058
A- 4........	6.6	4.04	7.36	.094	.118
A- 5........	8.2	4.91	5.93	.086	.111
A- 6........	11.2	5.65	7.59	.044	.037
A- 7........	12.1	2.61	9.42	.050	.210
A- 8........	13.9	5.87	7.18	.113	.141
A- 9........	15.5	10.63	8.56	.086	.097
A-10........	17.4	10.63	10.47	.078	.100
A-11........	18.4	10.71	10.55	.051	.054
A-12........	19.6	10.87	12.45	.045	.059
A-13........	22.0	7.04	14.39	.042	.053
A-14........	24.6	6.60	10.75	.037	.047
A-15........	27.7	7.14	7.68	.046	.060

TABLE 15.--Average slope and adjusted "n" values--Continued

Cross section No.	Location river mile	Average slope in feet per mile		Adjusted "n" value	
		Channel	Overbank	Channel	Overbank
	Walnut Creek (cont'd)				
A-16........	29.8	9.37	11.48	0.070	0.090
A-17........	31.8	14.35	14.80	.043	.049
	Homer Creek				
A-20........	2.3	7.65	9.65	.091	.117
A-21........	5.0	8.69	9.97	.099	.126
A-22........	7.1	11.41	13.47	.059	.074
A-23........	10.1	11.48	15.18	.046	.053
A-24........	12.6	7.61	12.64	.099	.125
A-25........	16.1	6.10	10.81	.103	.129
	West Creek				
B- 1........	2.4	7.24	3.23	.036	.045
B- 2........	3.6	3.72	4.50	.042	.050
B- 3........	6.6	4.59	7.20	.034	.045
B- 4........	9.6	5.29	8.71	.055	.074
B- 5........	12.6	6.72	8.52	.050	.067
B- 6........	14.2	10.28	8.05	.060	.080
B- 7........	16.6	10.87	14.43	.070	.090
B- 8........	19.2	9.93	16.74	.064	.081
B- 9........	22.3	8.07	12.39	.080	.100
B-10........	24.0	8.78	12.37	.085	.105
B-11........	26.6	10.54	12.34	.085	.105
	Willow Creek				
B-20........	2.2	6.75	9.22	.033	.045
B-21........	3.9	5.70	8.83	.034	.044
B-22........	7.3	6.25	9.56	.037	.050
B-23........	9.8	6.02	11.71	.041	.054
B-24.........	12.8	8.84	12.34	.062	.077
B-25........	15.8	11.56	12.32	.080	.100
	Bernard Brarch				
C- 1........	2.6	12.91	12.49	.070	.090
C- 2........	4.8	15.00	17.09	.085	.105
C- 3........	6.4	14.34	15.79	.075	.095
C- 4........	7.8	14.19	15.31	.074	.092
C- 5........	9.5	14.76	15.31	.070	.085

TABLE 16.--Cross-section rating table stage vs. discharge

Cross section No.	Location river mile	Discharge in c.f.s.,- Zero flow	1,000	2,000	5,000	10,000	15,000	20,000	30,000	40,000	50,000	60,000	80,000	100,000	110,000	115,000	130,000
		Water-surface elevation, mean sea level															
	Main stem																
RM 268.0..	268.0	845.3	857.7	861.9	869.3	877.3	880.7	881.5	882.9	883.4	884.0	884.5	885.2	886.0	886.2	886.3	886.6
RM 270.3..	270.3	851.7	862.7	865.9	871.5	877.5	881.2	884.6	887.0	888.1	889.0	889.9	890.9	891.9	892.1	892.3	892.8
RO-V-56...	273.4	856.8	871.0	874.3	880.0	885.4	889.4	892.8	894.3	895.7	896.7	897.5	899.0	900.0	900.7	901.0	901.8
RM 275.3..	275.3	864.6	871.2	875.2	882.7	890.0	895.0	899.5	901.0	902.0	903.0	903.8	904.8	905.7	906.0	906.2	907.0
RM 279.0..	279.0	874.7	888.8	891.8	897.0	902.0	905.4	908.0	909.8	911.0	911.9	912.6	914.0	915.0	915.4	915.8	916.7
RM 281.9..	281.9	889.0	897.4	899.5	904.1	910.1	914.3	915.8	917.5	919.0	920.3	921.2	923.0	924.2	924.9	925.1	926.0
RO-V-58...	283.0	894.5	898.9	901.2	906.2	912.0	915.8	917.0	919.0	920.5	921.8	922.9	924.4	926.0	926.4	926.8	927.4
RM 287.5..	287.5	905.0	909.9	913.4	920.5	928.7	930.6	931.5	932.8	933.9	934.5	935.0	936.0	937.0	937.2	937.4	938.0
RM 290.5..	290.5	910.7	916.7	920.7	928.8	933.1	935.4	937.2	939.5	940.5	941.5	942.0	943.3	944.0	944.5	944.5	945.0
RO-V-61...	297.2	930.2	933.4	934.9	938.0	941.6	944.2	946.7	950.6	954.0	956.5	957.3	958.8	960.0	960.3	960.5	961.2
RM 300.8..	300.8	941.9	945.5	947.5	951.5	955.8	959.0	961.7	964.9	966.0	967.3	968.3	970.0	971.2	971.7	971.9	972.0
RO-V-62...	303.7	951.5	955.4	957.1	960.6	964.4	967.2	969.7	973.8	976.2	977.3	978.2	979.8	981.0	981.5	981.8	982.4
RO-V-63...	306.8	966.8	969.6	971.1	974.2	977.8	980.5	982.8	986.7	990.0	993.0	994.0	995.8	997.0	997.4	997.8	998.5
RO-V-64...	311.3	985.9	989.7	991.3	994.4	997.8	1,000.0	1,002.0	1,005.2	1,007.9	1,010.4	1,012.5	1,016.0	1,018.5	1,019.1	1,019.6	1,020.8
RO-V-65...	313.9	1,002.8	1,003.6	1,005.2	1,008.6	1,012.7	1,015.7	1,018.3	1,022.9	1,024.5	1,026.0	1,027.3	1,029.5	1,031.1	1,032.0	1,032.4	1,033.4
RO-V-66...	317.3	1,023.4	1,028.2	1,030.4	1,035.0	1,038.8	1,040.0	1,041.0	1,042.7	1,043.8	1,044.7	1,045.5	1,046.9	1,048.0	1,048.3	1,048.6	1,049.2
RO-V-67...	322.0	1,037.7	1,042.0	1,043.6	1,046.6	1,049.7	1,051.9	1,053.8	1,056.6	1,059.0	1,061.0	1,062.9	1,066.0	1,068.0			
RO-V-68...	330.0	1,076.6	1,080.6	1,082.3	1,085.5	1,089.0	1,091.5	1,093.6	1,097.0	1,100.0	1,101.5	1,102.9	1,105.0	1,107.0			
D- 1......	334.7	1,112.9	1,118.1	1,120.4	1,124.9	1,129.9	1,133.2	1,134.8	1,137.1	1,139.0	1,140.6	1,142.0					
D- 2......	339.3	1,133.4	1,145.0	1,148.4	1,153.2	1,155.7	1,157.4	1,158.8	1,160.6	1,162.0	1,163.3	1,164.0					
D- 3......	342.2	1,165.8	1,173.6	1,175.7	1,179.3	1,182.8	1,184.8	1,186.2	1,188.7	1,190.5	1,192.1	1,193.5					
D- 4......	343.9	1,195.5	1,201.3	1,203.6	1,205.7	1,207.7	1,209.0	1,210.0	1,211.6	1,212.9							
D- 5......	345.2	1,216.2	1,219.3	1,220.6	1,223.3	1,226.2	1,228.5	1,230.4	1,232.8	1,234.1							
D- 6......	347.5	1,250.4	1,254.7	1,256.3	1,259.0	1,261.9	1,263.8	1,264.9	1,266.6	1,267.9							
	Walnut Creek																
A- 1......	2.7	883.3	888.8	891.0	895.4	900.1	903.6	906.5	910.1								
A- 2......	4.1	885.1	890.7	893.1	898.0	903.5	907.7	911.2	913.2								
A- 3......	5.1	889.0	894.6	896.7	900.9	905.5	908.8	911.7	915.1								
A- 4......	6.6	897.5	906.7	909.8	915.3	919.9	921.6	923.0	925.0								
A- 5......	8.2	901.4	910.7	914.4	921.2	925.8	927.8	929.5	931.6								
A- 6......	11.2	920.3	925.2	927.3	931.2	935.5	937.9	939.0	940.8								
A- 7......	12.1	923.6	934.0	938.6	941.9	944.8	946.6	948.2	950.4								
A- 8......	13.9	927.3	938.8	945.0	951.9	954.4	956.1	957.5	959.2								
A- 9......	15.5	943.8	949.8	952.6	958.7	964.2	967.1	969.5	973.4								
A-10......	17.4	964.3	971.6	974.8	978.5	982.0	984.5	986.5	989.6								
A-11......	18.4	974.3	979.7	982.3	987.6	991.4	993.5	994.1	997.9								
A-12......	19.6	988.5	994.5	996.7	1,000.3	1,002.6	1,004.0	1,005.2									
A-13......	22.0	1,013.1	1,017.1	1,019.1	1,023.3	1,027.2	1,028.5	1,029.8									
A-14......	24.6	1,023.0	1,031.4	1,034.3	1,039.7	1,042.0	1,043.4										
A-15......	27.7	1,050.9	1,057.3	1,059.8	1,064.8	1,066.9	1,068.3										
A-16......	29.8	1,060.7	1,070.7	1,074.9	1,078.0	1,080.5											
A-17......	31.8	1,089.4	1,094.7	1,097.0	1,101.1	1,102.7											

	Homer Creek									
A-20......	2.3	950.0	958.4	961.5	966.5	969.0	970.8	972.0	974.0	
A-21......	5.0	972.4	980.3	982.9	986.0	988.9	990.8	992.0	994.3	
A-22......	7.1	992.3	999.5	1,002.4	1,006.2	1,008.5	1,010.0	1,011.2		
A-23......	10.1	1,030.9	1,036.8	1,038.9	1,041.1	1,043.2	1,044.8	1,045.8		
A-24......	12.6	1,055.3	1,063.4	1,064.0	1,065.0	1,065.9	1,066.8			
A-25......	16.1	1,076.7	1,083.4	1,085.6	1,088.1	1,090.0	1,091.1			
	West Creek									
B- 1......	2.4	928.2	932.3	934.3	938.6	943.8	947.8	949.8	951.4	952.6
B- 2......	3.6	931.7	937.8	939.5	942.9	946.4	948.4	949.9	952.2	954.0
B- 3......	6.6	943.5	948.7	951.2	956.1	961.0	963.5	965.6	968.9	971.4
B- 4......	9.6	959.5	964.4	967.1	972.8	979.5	981.3	982.5	984.1	985.4
B- 5......	12.6	975.4	983.2	985.5	989.8	994.0	997.0	998.7	1,001.0	1,002.9
B- 6......	14.2	990.2	994.6	996.6	1,001.0	1,006.0	1,008.5	1,009.9	1,011.9	1,013.4
B- 7......	16.6	1,016.3	1,023.2	1,025.8	1,030.8	1,033.2	1,035.0	1,036.2	1,038.2	1,039.8
B- 8......	19.2	1,043.8	1,050.6	1,054.4	1,057.9	1,059.5	1,060.6	1,061.4	1,062.8	1,063.7
B- 9......	22.3	1,075.3	1,081.7	1,084.2	1,085.3	1,086.2	1,087.0	1,087.4	1,088.0	1,088.5
B-10......	24.0	1,083.1	1,091.2	1,094.0	1,098.0	1,100.0	1,101.5	1,102.6		
B-11......	26.6	1,110.3	1,116.9	1,119.0	1,122.0	1,124.9	1,126.7	1,128.0		
	Willow Creek									
B-20......	2.2	1,011.8	1,016.8	1,019.1	1,023.6	1,026.1	1,027.9	1,029.2		
B-21......	3.9	1,018.5	1,022.6	1,024.5	1,028.2	1,032.6	1,035.8	1,038.6		
B-22......	7.3	1,040.4	1,046.4	1,048.6	1,052.6	1,056.0	1,057.3	1,058.5		
B-23......	9.8	1,055.1	1,062.1	1,065.1	1,067.2	1,068.8	1,069.7	1,070.5		
B-24......	12.8	1,073.5	1,086.2	1,087.8	1,089.8	1,091.6	1,092.8	1,093.5		
B-25......	15.8	1,108.3	1,116.2	1,118.1	1,120.9	1,123.1	1,124.7	1,126.0		
	Bernard Branch									
C- 1......	2.6	1,090.4	1,096.1	1,099.0	1,105.2	1,110.8	1,112.5	1,113.9	1,116.0	1,117.4
C- 2......	4.8	1,123.0	1,129.3	1,132.1	1,136.3	1,139.2	1,141.1	1,142.8	1,145.1	1,147.0
C- 3......	6.4	1,146.7	1,153.5	1,155.9	1,160.4	1,163.9	1,165.6	1,167.0	1,169.0	1,170.6
C- 4......	7.8	1,165.9	1,171.7	1,174.6	1,180.0	1,182.3	1,183.6	1,184.8	1,186.3	1,187.6
C- 5......	9.5	1,190.7	1,196.3	1,198.2	1,201.9	1,205.4	1,207.1	1,208.5	1,210.7	1,212.4

TABLE 17.--Discharge vs. storage

Routing reach No.	Limits of routing reach	Discharge at lower limit of reach -											
		2,000	5,000	10,000	15,000	20,000	30,000	40,000	60,000	80,000	100,000	115,000	130,000
		Reach storage in 100,000 cubic feet											
	Main Stem												
1.....	RM 347.5 to RM 339.3	287	626	1,108		1,959	2,792	3,615					
2.....	RM 339.3 to RM 330.0	295	618	1,189		2,168	3,074	4,059	5,757				
3.....	RM 330.0 to RM 322.0	323	689	1,204		2,091	2,893	3,656	4,956	6,362	7,665		
4.....	RM 322.0 to RM 313.9	460	766	1,472		2,695	3,635	4,586	6,363	8,241	10,039		
5.....	RM 313.9 to RM 306.8	239	486	828		1,402	2,023	2,502	3,712	4,972	6,129	6,804	
6.....	RM 306.8 to RM 300.8	183	373	625		1,035	1,367	2,087	3,223	4,230	5,302	5,882	
7.....	RM 300.8 to RM 290.5	377	903	1,388		2,613	3,780	4,798	7,090	8,919	10,577	11,495	12,808
8.....	RM 290.5 to RM 281.9	567	837	1,957		4,059	5,555	6,859	9,112	11,313	13,380	14,593	16,169
9.....	RM 281.9 to RM 275.3	429	783	1,332		3,529	4,465	5,387	7,096	8,746	10,101	11,010	12,145
10.....	RM 275.3 to RM 268.0	675	1,112	1,690		4,246	5,331	7,301	9,437	11,382	12,918	13,894	15,407
	Walnut Creek												
1A.....	A-24 to A-21	349	798	1,279	1,773								
2A.....	A-21 to A- 7	398	913	1,629	2,420	3,175	4,608						
3A.....	A-15 to A-11	243	623	1,020	1,407								
4A.....	A-11 to A- 7	287	592	1,129	1,583	2,053	2,866						
5A.....	A- 7 to A- 3	264	705	1,406	2,000	2,627	3,796						
6A.....	A- 3 to Mouth	64	200	485	814	1,259	3,033						
	West Creek												
1B.....	B-24 to B-20	328	644	1,119		1,774	2,618						
2B.....	B- 9 to Junction	300	712	1,294	1,863	2,152	3,471	4,390					
3B.....	B-20 to B- 3	258	624	1,218		2,413	3,410						
4B.....	B- 3 to Mouth	162	357	716	1,039	1,477	2,353	3,340					
	Bernard Branch												
1C.....	C- 3 to Mouth	205	447	910	1,365	1,779	1,993						

TABLE 18.--Sample routing sheet, flood of April 12-16, 1947, Walnut Creek

(1)		(2)		(3)	(4)	(5)		(6)
Time Date and Hour		Inflow into head of reach 1A (subarea 14)		Column 2 routed through reach 1A	Reach 1A local inflow (subarea 19)	Inflow into head of reach 2A (col. 3 + 4)		Column 5 routed through reach 2A
		I	$I_1 + I_2$			I	$I_1 + I_2$	
		C.f.s.	*C.f.s.*	*C.f.s.*	*C.f.s.*	*C.f.s.*	*C.f.s.*	*C.f.s.*
April 12....	9:00 a.m.	0	0	0	0	0	0	0
		220	220	25	180	205	205	25
	12:00 m.	860	1,080	155	800	955	1,160	160
		1,350	2,210	400	1,425	1,825	2,780	455
	3:00 p.m.	970	2,320	595	1,100	1,695	3,520	775
		600	1,570	645	750	1,395	3,090	965
	6:00 p.m.	210	810	580	390	970	2,365	1,010
		0	210	450	0	450	1,420	940
	9:00 p.m.	0	0	320	0	320	770	800
		560	560	305	600	905	1,225	755
	12:00 p.m.	2,350	2,910	605	2,275	2,880	3,785	1,030
		2,900	5,250	1,140	3,350	4,490	7,370	1,700
April 13....	3:00 a.m.	1,800	4,700	1,475	2,300	3,775	8,265	2,350
		730	2,530	1,400	1,250	2,650	6,425	2,520
	6:00 a.m.	0	730	1,120	175	1,295	3,945	2,360
			0	820	0	820	2,115	2,000
	9:00 a.m.	0	0	600	0	600	1,420	1,650
		625	625	515	900	1,415	2,015	1,480
	12:00 m.	1,200	1,825	620	1,030	1,650	3,065	1,500
		1,050	2,250	750	920	1,670	3,320	1,520
	3:00 p.m.	1,330	2,380	865	1,250	2,115	3,785	1,550
		1,240	2,570	970	1,340	2,310	4,425	1,700
	6:00 p.m.	760	2,000	975	900	1,875	4,185	1,775
		300	1,060	850	470	1,320	3,195	1,700
	9:00 p.m.	0	300	660	50	710	2,030	1,510
			0	480	0	480	1,190	1,225
	12:00 p.m.	...	...	345	...	345	825	1,025
		...	...	240	...	240	585	840
April 14....	3:00 a.m.	...	...	175	...	175	415	685
		...	...	125	...	125	300	550
	6:00 a.m.	...	...	85	...	85	210	440
		...	...	60	...	60	145	345
	9:00 a.m.	...	...	40	...	40	100	275
		...	...	20	...	20	60	210
	12:00 m.	...	...	5	...	5	25	155
		...	...	0	...	0	5	115
	3:00 p.m.	...	...	...	...	...	0	80
		...	...	...	...	...	...	60
	6:00 p.m.	...	...	...	...	...	...	40
		...	...	...	...	...	...	25
	9:00 p.m.	...	...	...	...	...	...	10
		...	...	...	...	...	...	5
	12:00 p.m.	...	...	...	...	...	...	0
		...	...	...	...	...	...	...
April 15....	3:00 a.m.	...	...	...	...	...	...	...
	6:00 a.m.	...	...	...	...	...	...	...
	9:00 a.m.	...	...	...	...	...	...	...
		19,055	38,110	18,415	21,455	39,870	79,740	38,315

TABLE 18.--Sample routing sheet, flood of April 12-16, 1947--Continued

(3)		(7)		(8)	(9)	(10)		(11)	(12)
Time Date and Hour		Inflow into head to reach 3A (subarea 18)		Column 7 routed through reach 3A	Reach 3A local inflow (subarea 20)	Inflow into head to reach 4A (col. 8 + 9)		Column 10 routed through reach 4A	Reach 4A local inflow (subarea 23)
		I	$I_1 + I_2$			I	$I_1 + I_2$		
		C.f.s.	C.f.s.	C.f.s.	C.f.s.	C.f.s.	C.f.s.	C.f.s.	C.f.s.
April 12..	9:00 a.m.	0	0	0	0	0	0	0	0
		220	220	25	220	245	245	30	225
	12:00 m.	800	1,020	170	900	1,070	1,315	175	925
		1,380	2,180	465	1,440	1,905	2,975	530	1,380
	3:00 p.m.	1,310	2,690	760	1,030	1,790	3,695	940	975
		960	2,270	895	610	1,505	3,295	1,165	550
	6:00 p.m.	610	1,570	855	200	1,055	2,560	1,200	140
		260	870	700	0	700	1,755	1,090	0
	9:00 p.m.	0	260	495	0	495	1,195	920	0
		650	650	430	700	1,130	1,625	880	850
	12:00 p.m.	2,350	3,000	800	2,950	3,750	4,880	1,405	3,300
		4,100	6,450	1,760	3,550	5,310	9,060	2,680	3,500
April 13..	3:00 a.m.	3,175	7,275	2,400	2,175	4,575	9,885	3,600	2,050
		2,070	5,245	2,460	850	3,310	7,885	3,960	625
	6:00 a.m.	930	3,000	2,100	0	2,100	5,410	3,400	0
		0	930	1,500	...	1,500	3,600	2,700	...
	9:00 a.m.	0	0	875	0	875	2,375	2,100	...
		625	625	650	775	1,425	2,300	1,750	...
	12:00 m.	1,240	1,865	750	1,430	2,180	3,605	1,765	...
		1,450	2,690	960	1,170	2,130	4,310	1,915	...
	3:00 p.m.	1,845	3,295	1,240	1,350	2,590	4,720	2,025	...
		2,200	4,045	1,550	1,560	3,110	5,700	2,340	...
	6:00 p.m.	1,375	3,575	1,640	1,340	2,980	6,090	2,600	...
		850	2,225	1,425	830	2,255	5,235	2,620	...
	9:00 p.m.	380	1,230	1,100	325	1,425	3,680	2,275	...
		0	380	750	0	750	2,175	1,800	...
	12:00 p.m.	...	0	480	...	480	1,230	1,380	...
		...	...	315	...	315	795	1,035	...
April 14..	3:00 a.m.	...	...	205	...	205	520	770	...
		...	...	140	...	140	345	585	...
	6:00 a.m.	...	...	95	...	95	235	445	...
		...	...	60	...	60	155	340	...
	9:00 a.m.	...	...	40	...	40	100	260	...
		...	...	25	...	25	65	190	...
	12:00 m.	...	...	10	...	10	35	140	...
		...	...	5	...	5	15	105	...
	3:00 p.m.	...	...	0	...	0	5	75	...
		...	...	...	...	...	0	55	...
	6:00 p.m.	...	...	...	...	...	...	35	...
		...	...	...	...	...	...	20	...
	9:00 p.m.	...	...	...	...	...	...	10	...
		...	...	...	...	...	...	5	...
	12:00 p.m.	...	...	...	...	...	...	0	...
April 15..	3:00 a.m.	...	...	...	...	...	...	...	...
	6:00 a.m.	...	...	...	...	...	...	...	...
	9:00 a.m.	...	...	...	...	...	...	...	...
		28,780	57,560	28,130	23,405	51,535	103,070	51,315	14,520

TABLE 18.--Sample routing sheet, flood of April 12-16, 1947--Continued

Time Date and Hour		(13)		(14)	(15)	(16)		(17)
		inflow into head of reach 5A (col. 6, 11 & 12)		Column 13 routed through reach 5A	Reach 5A local inflow (subarea 25)	Inflow into head of reach 6A (col. 14 + 15)		Column 16 routed through reach 6A to mouth of Walnut Creek
		I	$I_1 + I_2$			I	$I_1 + I_2$	
		C.f.s.	*C.f.s.*	*C.f.s.*	*C.f.s.*	*C.f.s.*	*C.f.s.*	*C.f.s.*
April 12....	9:00 a.m.	0	0	0	0	0	0	0
		280	280	35	350	385	385	165
	12:00 m.	1,260	1,540	270	660	930	1,315	605
		2,365	3,625	780	1,160	1,940	2,870	1,335
	3:00 p.m.	2,690	5,055	1,360	970	2,330	4,270	2,035
		2,680	5,370	1,805	670	2,475	4,805	2,300
	6:00 p.m.	2,350	5,030	2,075	380	2,455	4,930	2,400
		2,030	4,380	2,160	75	2,235	4,690	2,375
	9:00 p.m.	1,720	3,750	2,050	0	2,050	4,285	2,200
		2,475	4,205	2,080	625	2,705	4,755	2,250
	12:00 p.m.	5,735	8,220	2,725	2,300	5,025	7,730	3,420
		7,880	13,615	4,000	3,300	7,300	12,325	5,400
April 13....	3:00 a.m.	8,000	15,880	5,050	2,300	7,350	14,650	6,600
		7,105	15,105	5,780	1,300	7,080	14,430	7,000
	6:00 a.m.	5,760	12,865	5,925	250	6,175	13,255	6,800
		4,700	10,460	5,650	0	5,650	11,825	6,200
	9:00 a.m.	3,750	8,450	5,200	...	5,200	10,850	5,580
		3,230	6,980	4,620	...	4,620	9,820	5,010
	12:00 m.	3,265	6,495	4,200	...	4,200	8,820	4,500
		3,435	6,700	3,920	...	3,920	8,120	4,200
	3:00 p.m.	3,575	7,010	3,775	...	3,775	7,695	3,800
		4,040	7,615	3,780	...	3,780	7,555	3,750
	6:00 p.m.	4,375	8,415	3,900	...	3,900	7,680	3,800
		4,320	8,695	4,000	...	4,000	7,900	3,820
	9:00 p.m.	3,785	8,105	4,020	...	4,020	8,020	3,950
		3,025	6,810	3,800	...	3,800	7,820	3,900
	12:00 p.m.	2,405	5,430	3,425	...	3,425	7,225	3,740
		1,875	4,280	3,020	...	3,020	6,445	3,375
April 14....	3:00 a.m.	1,455	3,330	2,620	...	2,620	5,640	2,900
		1,135	2,590	2,210	...	2,210	4,830	2,500
	6:00 a.m.	885	2,020	1,850	...	1,850	4,060	2,200
		685	1,570	1,495	...	1,495	3,345	1,800
	9:00 a.m.	535	1,220	1,205	...	1,205	2,700	1,400
		400	935	960	...	960	2,165	1,055
	12:00 m.	295	695	650	...	650	1,610	835
		220	515	585	...	585	1,235	630
	3:00 p.m.	155	375	445	...	445	1,030	535
		115	270	335	...	335	780	400
	6:00 p.m.	75	190	245	...	245	580	295
		45	120	185	...	185	430	220
	9:00 p.m.	20	65	125	...	125	310	165
		10	30	80	...	80	205	125
	12:00 p.m.	0	10	50	...	50	130	80
		...	0	25	...	25	75	40
April 15....	3:00 a.m.	...	...	10	...	10	35	20
		...	...	5	...	5	15	5
	6:00 a.m.	...	...	0	...	0	5	0
		...	...	...	...	...	0	...
	9:00 a.m.	...	...	...	...	...	...	...
		104,150	208,300	102,485	14,340	116,825	233,650	115,715

TABLE 19.

Subarea No.	Drainage area		Cultivated land (acres)								
			Total present acres cult.	Row crops				Legumes, grasses, and small grains			
				Straight		Terraced		Straight		Terraced	
	Square miles	Total acres		Present	Future	Present	Future	Present	Future	Present	Future
Cover Practice Indices				20.4	14.6	12.7	10.4	18.5	13.3	14.8	11.2
1.........	29.0	18,536	0	0	0	0	0	0	0	0	0
2.........	29.1	18,648	2,300	746	200	174	355	1,104	199	276	1,378
3.........	26.0	16,640	4,000	1,280	347	320	614	1,920	347	480	2,363
4.........	16.2	10,368	240	77	20	19	37	115	21	29	142
5.........	32.0	20,480	1,185	379	103	95	183	569	103	142	701
6.........	34.7	22,208	4,670	1,495	405	374	720	2,241	406	560	2,766
7.........	32.7	20,928	4,219	1,350	367	338	651	2,024	367	507	2,086
8.........	26.0	16,640	3,090	988	268	247	476	1,484	268	371	1,830
9.........	25.8	16,512	4,920	1,569	427	399	758	2,353	427	599	2,914
10.........	31.2	19,968	3,340	1,069	290	267	515	1,603	290	401	1,978
11.........	20.9	13,376	5,101	1,632	442	407	786	2,450	443	612	3,430
12.........	27.7	17,728	4,590	1,469	398	367	708	2,203	399	551	2,717
13.........	27.4	17,536	4,460	1,427	387	357	688	2,141	387	535	2,540
14.........	23.5	15,040	3,370	1,078	292	270	519	1,618	293	404	1,995
15.........	27.8	17,792	3,930	1,258	341	314	606	1,886	341	472	2,327
16.........	23.3	14,912	2,070	662	179	166	318	994	180	248	1,227
17.........	35.2	22,528	4,820	1,542	418	386	743	2,314	419	578	2,853
18.........	31.0	19,840	4,540	1,453	394	363	700	2,179	394	545	2,688
19.........	27.6	17,664	5,050	1,616	438	404	778	2,424	439	606	2,991
20.........	24.4	15,616	4,610	1,564	400	280	711	2,346	400	420	2,729
21.........	12.9	8,256	1,560	499	135	125	240	749	136	187	925
22.........	36.2	23,168	4,060	1,299	352	325	626	1,949	353	487	2,403
23.........	27.7	17,728	2,920	934	253	234	449	1,402	254	350	1,727
24.........	20.2	12,928	4,130	1,322	358	330	637	1,982	359	496	2,445
25.........	27.0	17,280	2,100	672	182	168	323	1,008	183	252	1,244
26.........	24.8	15,872	3,550	1,136	308	284	547	1,704	308	426	2,102
27.........	24.0	15,360	1,850	592	160	148	285	888	161	222	1,095
28.........	22.7	14,528	4,570	1,462	396	366	705	2,194	397	548	2,706
Grand Total......	747.0	478,080	95,245	30,570	8,260	7,527	14,678	45,844	8,274	11,304	56,302
Percent....	100%		19.9%								
Future.....			87,514								
Percent....			18.3%								

TABLE 20.--Damageable values per acre of flood-plain land in reach 1

Crop	Damageable area per acre	Percent in each crop use	Yield per acre	Production per flood-plain acre	Value	Damageable value per acre
	Acres	*Percent*			*Dollars*	*Dollars*
Wheat...............	176	32.4	27 bu.	8.75	2.14 per bu.	18.72
Corn.................	142	26.2	39 bu.	10.22	1.69 per bu.	17.27
Soybeans............	23	4.2	16 bu.	.67	2.71 per bu.	1.82
Sorghum silage......	20	3.7	9 tons	.33	12.20 per ton	4.03
Alfalfa.............	74	13.6	3.3 tons	.45	31.63 per ton	14.23
Temporary pasture...	...	...	2.5 AUM[1]	...	4.00 per AUM[1]	...
Native pasture.......	108	19.9	1.2 AUM[1]	.24	4.00 per AUM[1]	.96
Total	543	...	...	...	...	57.03

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[1] Animal unit month.

-Cover condition classes

Pasture (acres)							Woods (acres)						
Total present acres grass	Good		Fair		Poor		Total present acres woods	Good		Fair		Poor	
	Present	Future	Present	Future	Present	Future		Present	Future	Present	Future	Present	Future
	5.3	5.3	7.3	7.3	9.3	9.3		1.4	1.4	3.3	3.3	5.3	5.3
18,536	926	11,123	7,416	5,560	10,194	1,853	0	0	0	0	0	0	0
16,348	818	9,910	6,538	4,954	8,992	1,652	0	0	0	0	0	0	0
12,025	601	7,412	4,810	3,707	6,614	1,235	615	31	308	246	215	338	92
9,208	460	5,536	3,684	2,769	5,064	923	920	46	460	368	322	506	138
18,350	917	11,067	7,340	5,534	10,093	1,844	945	47	472	379	331	519	142
16,888	845	10,356	6,755	5,180	9,288	1,726	650	33	325	260	227	357	97
15,970	799	10,192	6,387	4,895	8,784	1,630	739	44	369	289	266	406	105
13,550	678	8,278	5,420	4,141	7,452	1,379	0	0	0	0	0	0	0
11,242	562	6,981	4,497	3,492	6,183	1,163	350	35	175	123	140	192	35
16,308	815	9,945	6,524	4,973	8,969	1,657	320	32	160	112	128	176	32
7,769	388	4,500	3,109	2,451	4,272	818	506	50	253	177	203	279	50
12,863	643	7,938	5,145	3,970	7,075	1,323	275	27	138	97	110	151	27
13,076	654	7,888	5,230	4,235	7,192	1,411	0	0	0	0	0	0	0
11,670	584	7,164	4,668	3,583	6,418	1,194	0	0	0	0	0	0	0
13,237	662	8,131	5,295	4,067	7,280	1,355	625	62	312	219	250	344	62
11,867	593	7,219	4,747	3,612	6,527	1,203	975	97	487	342	390	536	97
16,808	840	10,317	6,723	5,159	9,245	1,719	900	90	450	315	360	495	90
15,300	765	9,399	6,120	4,699	8,415	1,566	0	0	0	0	0	0	0
12,154	608	7,534	4,862	3,769	6,684	1,255	460	138	253	230	161	92	46
10,356	518	6,435	4,142	3,219	5,696	1,072	650	195	358	325	227	130	65
6,156	308	3,768	2,462	1,884	3,386	628	540	162	297	270	189	108	54
18,183	909	11,106	7,274	5,553	10,000	1,850	925	277	509	463	324	185	92
14,123	706	8,615	5,649	4,311	7,768	1,435	685	206	377	342	239	137	68
7,923	396	4,953	3,169	2,477	4,358	825	875	263	481	437	306	175	87
14,560	728	8,837	5,824	4,418	8,008	1,473	620	186	341	310	217	124	62
10,442	522	6,437	4,177	3,218	5,743	1,072	1,880	564	1,034	940	658	376	188
11,550	577	7,019	4,620	3,509	6,353	1,171	1,960	588	1,078	980	686	392	196
9,283	464	5,789	3,713	2,896	5,106	965	675	203	371	337	236	135	67
365,745	18,286	223,849	146,300	112,235	201,159	37,397	17,090	3,375	9,008	7,562	6,185	6,153	1,892
76.5%							3.6%						
373,481							17,085						
78.1%							3.6%						

TABLE 21.--Composite crop and pasture damage per acre flooded by depth of flooding for reach 1, June

Crop	Damageable value per acre	Net damage					
		Depth 0-1 foot		Depth 1-3 feet		Depth more than 3 feet	
	Dollars	*Percent*	*Dollars*	*Percent*	*Dollars*	*Percent*	*Dollars*
Wheat....................	18.72	40	7.49	60	11.23	70	13.10
Corn.....................	17.27	30	5.18	40	6.91	55	9.50
Soybeans.................	1.82	20	.36	35	.64	45	.82
Sorghum silage...........	4.03	15	.60	30	1.21	45	1.81
Alfalfa..................	14.23	20	2.85	27	3.84	40	5.69
Temporary pasture........	...	10	...	15	...	20	...
Native pasture...........	.96	20	.19	25	.24	32	.31
Composite acre damage			16.67		24.07		31.23

Table 22 - Discharge vs. Area flooded

Cross Section Number	Location River Mile	Zero Flooding Elev.(MSL)	Discharge in cfs														
			1,000	2,000	5,000	10,000	15,000	20,000	30,000	40,000	50,000	60,000	80,000	100,000	110,000	115,000	130,000
			Area Flooded in Reach in Acres														
	Main Stem																
RM 268.0	268.0	862.5	0	0	3	7	260	532	555	558	559	567	650	662	667	670	678
RM 270.3	270.3	862.0	7	12	17	23	30	105	1,042	1,168	1,275	1,375	1,408	1,425	1,432	1,435	1,445
RO-V-56	273.4	864.0	19	26	44	135	608	985	1,240	1,337	1,358	1,375	1,402	1,423	1,432	1,435	1,445
RM 275.3	275.3	878.0	0	0	3	10	240	552	576	586	600	607	617	625	629	632	638
RM 279.0	279.0	891.0	0	0	5	14	340	910	1,070	1,127	1,165	1,195	1,252	1,296	1,306	1,311	1,326
RM 281.9	281.9	892.8	0	6	18	46	332	532	700	840	962	1,020	1,044	1,060	1,068	1,072	1,083
RO-V-58	283.0	894.5	4	7	20	55	290	443	677	965	1,175	1,240	1,270	1,288	1,297	1,302	1,317
RM 287.5	287.5	916.5	0	0	5	1,100	1,825	2,180	2,610	2,920	3,140	3,305	3,165	3,410	3,435	3,440	3,470
RM 290.5	290.5	925.0	0	0	58	410	775	1,160	1,380	1,415	1,423	1,429	1,440	1,445	1,449	1,451	1,455
RO-V-61	297.2	931.0	10	17	30	50	65	75	92	510	1,265	1,335	1,400	1,445	1,463	1,473	1,496
RM 300.8	300.8	954.0	0	0	0	5	15	63	410	590	735	865	1,100	1,155	1,175	1,185	1,215
RO-V-62	303.7	956.0	0	5	17	32	43	52	145	350	575	930	1,070	1,103	1,118	1,125	1,145
RO-V-63	306.8	966.8	10	16	27	40	50	56	70	83	835	1,035	1,253	1,260	1,264	1,265	1,268
RO-V-64	311.3	987.0	7	12	47	87	97	107	122	137	150	350	489	515	524	528	532
RO-V-65	313.9	1,003.0	4	13	25	38	47	108	246	338	411	446	462	476	481	485	492
RO-V-66	317.3	1,023.4	14	23	63	415	608	810	1,343	1,366	1,387	1,403	1,430	1,460	1,475	1,485	1,507
RO-V-67	322.0	1,039.0	56	87	133	192	236	288	350	385	640	896	1,360	1,704			
RO-V-68	330.0	1,077.5	30	49	82	118	156	195	394	616	692	720	808	880			
D- 1	334.7	1,119.5	0	7	34	62	205	295	385	562	727						
D- 2	339.3	1,148.0	0	5	155	227	450	660	727	755	763						
D- 3	342.2	1,170.5	24	35	67	133	182	222	269	292							
D- 4	343.9	1,199.5	3	31	76	130	140	151	174								
D- 5	345.2	1,221.5	0	0	5	10	12	55	130								
D- 6	347.5	1,252.5	5	10	18	55	135	162	182								
	Walnut Creek																
A- 1	2.7	900.0	0	0	0	5	54	122	263								
A- 2	4.1	901.5	0	0	0	7	18	68	215								
A- 3	5.1	906.5	0	0	0	0	20	22	70								
A- 4	6.6	911.5	0	0	31	138	234	328	336								
A- 5	8.2	918.0	0	0	28	140	224	283	330								
A- 6	11.2	934.0	0	0	0	21	54	139	188								
A- 7	12.1	937.0	0	14	78	155	223	244	246								
A- 8	13.9	949.5	0	0	73	260	304	326	342								
A- 9	15.5	949.5	2	11	18	58	66										
A-10	17.4	971.0	5	23	47	73	85										
A-11	18.4	986.5	0	0	7	20	46										
A-12	19.6	996.0	0	1	52	94	121										
A-13	22.0	1,020.0	0	0	10	120	170										
A-14	24.6	1,031.0	0	3	79	129	140										
A-15	27.7	1,060.5	0	0	67	237	265										

A-16	29.8	1,075.0	0	0	108	196				
A-17	31.8	1,100.0	0	0	82	177				
	Homer Creek									
A-20	2.3	963.0	0	0	171	297	308			
A-21	5.0	974.0	15	52	161	218	311			
A-22	7.1	1,003.0	0	0	134	156	171			
A-23	10.1	1,037.0	0	45	88	126	135			
A-24	12.6	1,061.5	360	597	604	612	617			
A-25	16.1	1,081.0	31	127	430	622				
	West Creek									
B- 1	2.4	940.0	0	0	0	18	77	565	682	710
B- 2	3.6	934.0	6	8	11	85	136	155	250	370
B- 3	6.6	957.0	0	0	0	44	64	82	320	412
B- 4	9.6	975.0	0	0	0	124	234	380	464	476
B- 5	12.6	985.5	0	0	20	65	81	200	240	261
B- 6	14.2	1,000.5	0	0	2	45	85	122	177	182
B- 7	16.6	1,026.0	0	0	93	295	342	359		
B- 8	19.2	1,055.0	0	0	224	250	254	259		
B- 9	22.3	1,079.5	7	340	547	570	580	586		
B-10	24.0	1,089.0	5	7	122	156	168			
B-11	26.6	1,115.0	8	36	94	114	117			
	Willow Creek									
B-20	2.2	1,020.5	0	0	86	108	125	148	185	
B-21	3.9	1,022.0	1	2	3	9	18	47		
B-22	7.3	1,049.0	0	0	5	135	172	188		
B-23	9.8	1,061.5	2	28	136	280	291	299		
B-24	12.8	1,085.0	20	120	150	178	206	223		
B-25	15.8	1,114.0	26	56	145	158	163			
	Bernard Branch									
C- 1	2.6	1,102.5	0	0	20	154	443	472	513	
C- 2	4.8	1,132.5	0	0	71	110	163	182		
C- 3	6.4	1,155.5	0	4	38	105	138	178		
C- 4	7.8	1,176.0	0	0	60	172	210	226		
C- 5	9.5	1,193.0	2	4	31	90	115	172		

TABLE 23.--Crop and pasture damages, and benefits for all reaches

MAIN STEM.

Reach No.	Average damage per year				Average benefits per year		
	Present conditions	Land treatment only	Structures only	Structures and land treatment	Land treatment only	Structures only	Structures and land treatment
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1	5,203	4,163	2,945	2,457	1,040	2,258	2,746
2	6,825	5,549	4,112	3,449	1,276	2,713	3,376
3	7,587	6,545	5,664	4,979	1,042	1,923	2,608
4	16,620	13,003	9,760	7,426	3,617	6,860	9,194
5	6,042	5,060	3,771	2,988	982	2,271	3,054
6	7,182	5,774	3,196	2,539	1,408	3,986	4,643
7	18,473	14,042	8,692	6,843	4,431	9,781	11,630
8	62,339	46,304	27,262	21,743	16,035	35,077	40,596
9	21,856	13,158	7,090	4,817	8,698	14,766	17,039
10	38,783	29,035	16,685	13,826	9,748	22,098	24,957
Subtotal	190,910	142,633	89,177	71,067	48,277	101,733	119,843
TRIBUTARIES							
1A	7,190	5,877	5,085	4,273	1,313	2,105	2,917
2A	10,586	7,533	1,925	1,426	3,053	8,661	9,160
3A	2,615	1,619	407	224	922	2,208	2,391
4A	1,610	1,148	1,010	839	462	600	771
5A	5,642	4,454	1,494	1,065	1,188	4,148	4,577
6A	1,697	885	25	19	812	1,672	1,678
1B	5,435	4,188	3,480	2,864	1,247	1,955	2,571
2B	6,273	3,893	3,092	2,308	2,380	3,181	3,965
3B	4,820	3,004	1,140	741	1,816	3,680	4,079
4B	4,222	2,837	1,085	839	1,385	3,137	3,383
1C	2,748	2,135	364	321	613	2,384	2,427
Subtotal	52,838	37,573	19,107	14,919	15,191	33,731	37,919
Total	243,748	180,206	108,284	85,986	63,468	135,464	157,762

TABLE 24.--Other agricultural damages July 1951 flood

Type	Amount
	Dollars
Fence	10,645
Livestock	1,593
Stored crops	12,341
Farm machinery	731
Farm buildings	4,510
Drainage ditches and dikes	1,146
Debris removal	2,161
Total damages	33,127
Acres flooded	5,181
Damage per acre	6.39

TABLE 25.--Runoff and triangular hydrograph characterisitics (sample worksheet)
April 13, 1947, storm, subarea No. 5, Coyville, Kansas

Symbol	Name	April 12 10 p.m.	April 13 9 a.m.	April 13 1 p.m.
S	Soil index...	0.097	0.097	0.097
D	Duration of storm .... hours...........	2.0	2.0	1.0
C_p	Cover-practice index (present condition)................	8.7	8.7	8.7
C_c	Cover-practice index (with land treatment).............	6.4	6.4	6.4
M	Antecedent rainfall index..............................	1.37	2.36	2.86
T	Seasonal index...	.9	.9	.9
B_p	Runoff index (present condition).......................	.29	.50	1.2
B_c	Runoff index (with land treatment).....................	.22	.38	.95
P	Excess precipitation .... inches..........	1.1	.5	.5
Q_p	Volume of runoff (present condition)... inches..........	.57	.22	.45
Q_c	Volume of runoff (with land treatment). inches..........	.47	.17	.32
A	Total area .... square miles....	32.0	32.0	32.0
T_c	Travel time.......................... hours...........	26.1	26.1	26.1
T_l	Lag time............................. hours...........	15.5	15.5	15.5
T_p	Time to peak......................... hours...........	16.5	16.5	16.0
R	Peak discharge per inch of runoff...... c. f. s.	925.0	925.0	975.0
T_R	Recession time....................... hours...........	27.6	27.6	26.7
q_p	Peak discharge (present condition)..... c. f. s.	527.0	204.0	440.0
q_c	Peak discharge (with land treatment)... c. f. s.	435.0	157.0	312.0

TABLE 26.--Sample computations of direct and base and subsurface flow, April 21-28, 1952, Coyville, Kans.

Time		Total runoff	Total base and subsurface runoff	Direct runoff	Previous base and subsurface runoff	Present base and subsurface runoff
		C.f.s.	C.f.s.	C.f.s.	C.f.s.	C.f.s.
April 21....	12:00 m.	780	740	40	660	80
	6:00 p.m.	890	760	130	620	140
	12:00 p.m.	1,700	810	890	570	240
April 22....	6:00 a.m.	4,450	855	3,595	530	325
	12:00 m.	6,050	900	5,150	495	405
	6:00 p.m.	7,400	950	6,450	470	480
	12:00 p.m.	8,250	1,000	7,250	440	560
April 23...	6:00 a.m.	7,700	1,075	6,625	420	655
	12:00 m.	6,100	1,100	5,000	395	705
	6:00 p.m.	4,100	1,125	2,975	378	747
	12:00 p.m.	2,600	1,075	1,525	359	716
April 24...	6:00 a.m.	1,650	1,025	625	340	685
	12:00 m.	1,175	960	215	320	640
	6:00 p.m.	1,000	920	80	305	615
	12:00 p.m.	...	880	...	290	590
Total.............				40,550		
April 25...	6:00 a.m.	...	830	...	275	555
	12:00 m.	...	780	...	260	520
	6:00 p.m.	...	740	...	247	493
	12:00 p.m.	...	690	...	235	455
April 26...	6:00 a.m.	...	660	...	220	440
	12:00 m.	...	610	...	210	400
	6:00 p.m.	...	580	...	200	380
	12:00 m.	...	560	...	190	370
April 27...	6:00 a.m.	...	530	...	180	350
	12:00 m.	...	510	...	170	340
	6:00 p.m.	...	443	...	160	283
	12:00 p.m.	...	436	...	155	281
April 28...	6:00 a.m.	...	430	...	148	282
	12:00 m.	...	420	...	140	280
Total.............						13,012

Computation of Additional Recession Volume

Total base and subsurface runoff $= \frac{420 \text{ c. f. s.} + 100 \text{ c. f. s.}}{2} \times 180$ hours $= 46{,}800$ c. f. s. hours

Previous base and subsurface runoff $= \frac{140 \text{ c. f. s.} + 100 \text{ c. f. s.}}{2} \times 36$ hours $= 4{,}320$ c. f. s. hours

Present base and subsurface runoff = 46,800 - 4,320 = 42,480 c. f. s. hours

Summation

Base and subsurface runoff:

$$\frac{13{,}012 \times 6 + 42{,}480}{482{,}039} = 0.25''$$

Direct runoff:

$$\frac{40{,}550 \times 6}{482{,}039} = 0.50''$$

TABLE 27.--Summary of storm series data, 1940-52, Coyville, Kans., gage, 747 square miles

Date and time of peak	Watershed rainfall	Duration rain	Peak	Volume direct runoff	Volume base and subsurface runoff	Total runoff	$P-Q_{SR}$
	Inches	*Days*	*C. f. s.*	*Inches*	*Inches*	*Inches*	*Inches*
April 17, 1940............ 12:00 m.	2.16	1	7,240	0.57	0.11	0.63	1.59
November 1, 1941........... 8:00 a.m.	1.21	1	10,700	.74	.26	1.00	.47
October 21, 1941........... 9:00 a.m.	1.47	2	10,000	.71	.19	.90	.76
September 30, 1941......... 12:00 p.m.	1.12	2	8,000	.70	.20	.90	.42
September 7, 1941.......... 4:30 p.m.	2.18	2	15,200	1.22	.15	1.37	.96
June 10, 1941.............. 8:00 a.m.	2.69	2	17,500	1.40	.26	1.66	1.29
June 1, 1941............... 8:00 a.m.	5.07	2	51,800	3.16	.25	3.41	1.91
April 15, 1941............. 2:00 a.m.	2.01	3	8,375	.90	.26	1.16	1.11
December 27, 1942.......... 3:00 p.m.	1.31	2	9,200	.53	.30	.93	.78
October 4, 1942........... 12:00 m.	1.43	1	9,300	.58	.18	.76	.85
September 6, 1942.......... 3:00 a.m.	5.20	3	11,700	1.32	.48	1.80	3.88
June 25, 1942............. 11:30 p.m.	1.76	1	13,600	1.01	.15	1.16	.75
April 28, 1942............ 12:00 m.	1.12	1	10,650	.60	.22	.82	.62
April 10, 1942............. 7:00 a.m.	.90	1	8,430	.46	.15	.61	.44
June 23, 1943 .... 4:00 a.m.	2.65	2	36,900	2.00	.30	2.30	.65
June 9, 1943.............. 12:00 p.m.	1.71	2	10,100	.55	.11	.66	1.16
May 24, 1943.............. 12:00 p.m.	1.57	1	13,300	.82	.14	.96	.75
May 19, 1943............... 6:00 p.m.	4.33	3	27,300	3.06	.40	3.46	1.27
December 5, 1944.......... 12:00 p.m.	3.46	3	19,200	1.64	.28	1.92	1.82
April 23, 1944......... 1:30-2:30 p.m.	3.39	3	40,300	2.52	.36	2.88	.87
April 11, 1944......... 6:30-8:30 p.m.	3.84	3	30,000	2.60	.45	3.05	1.24
March 22, 1944............. 4:00 a.m.	.97	1	7,560	.50	.22	.72	.47
March 18, 1944............. 3:30 p.m.	1.01	1	7,560	.42	.11	.53	.59
October 1, 1945............ 5:00 a.m.	4.19	3	16,600	1.98	.29	2.27	2.21
May 25, 1945.............. 10:00 p.m.	.60	1	8,150	.36	.08	.44	.24
April 26, 1945............. 3:00 p.m.	2.52	3	9,490	1.06	.53	1.59	1.46
April 16, 1945............ 12:30 p.m.	4.37	3	67,000	3.29	.43	3.72	1.08
April 11, 1945............ 12:00 m.	1.37	1	10,300	.46	.16	.62	.91
March 25, 1945............. 8:30 a.m.	2.11	1	27,800	1.50	.32	1.82	.61
April 23, 1946............. 4:30 a.m.	2.03	1	10,600	.37	.10	.47	1.66
June 27, 1947............. 11:30 p.m.	1.54	2	8,660	.65	.20	.82	.89
April 13, 1947............ 12:00 p.m.	2.25	2	16,600	1.39	.39	1.78	1.86
April 11, 1947............. 1:00 a.m.	1.76	1	9,270	.59	.10	.69	1.17
April 5, 1947.............. 4:30 p.m.	2.04	2	11,500	.79	.22	1.01	1.25
March 13, 1947............ 11:00 p.m.	2.62	2	12,000	.81	.21	1.02	1.81
July 20, 1948.............. 9:30 p.m.	6.86	3	65,500	6.16	.50	6.66	.70
July 24, 1949.............. 2:00 a.m.	2.31	2	13,200	1.24	.17	1.41	1.07
April 27, 1949............ 10:00 p.m.	1.40	1	7,550	.37	.10	.47	1.03
March 31, 1949............. 1:00 a.m.	1.27	1	10,500	.51	.15	.66	.76
January 24, 1949........... 9:00 p.m.	.81	2	7,250	.52	.17	.69	.29
August 30, 1950............ 5:30 a.m.	1.43	2	8,830	.52	.13	.65	.91
August 1, 1950............. 1:00 a.m.	1.75	3	8,980	.65	.15	.78	1.10
July 17, 1950.............. 1:00 p.m.	2.88	3	12,100	1.41	.33	1.74	1.47
July 11, 1950.............. 4:30 a.m.	2.99	2	10,300	.72	.07	.79	2.27
September 13, 1951......... 9:00 a.m.	1.26	2	14,200	.89	.18	1.07	.37
September 9, 1951.......... 7:00 p.m.	.65	1	8,200	.34	.07	.41	.31
September 6, 1951........... 6:00 a.m.	2.26	3	19,000	1.45	.36	1.81	.81
August 27, 1951............ 5:30 p.m.	1.86	3	8,100	.71	.15	.86	1.15
July 12, 1951.............. 1:00 a.m.	9.35	3	130,000	7.65	.39	8.04	1.70
July 4, 1951............... 5:00 a.m.	.97	2	10,500	.50	.26	.76	.47
June 30, 1951.............. 5:00 a.m.	4.53	3	46,400	3.94	.24	4.18	.59
June 24, 1951.............. 6:00 p.m.	1.82	2	12,200	1.01	.32	1.33	.81
May 2, 1951................ 5:00 a.m.	2.34	2	13,200	1.00	.17	1.17	1.34
April 23, 1952............ 12:30 a.m.	1.13	2	8,210	.49	.27	.76	.64
March 19, 1952............. 8:30 a.m.	.77	1	8,400	.43	.25	.68	.34
March 10, 1952............. 9:00 p.m.	.91	1	9,310	.57	.25	.82	.34

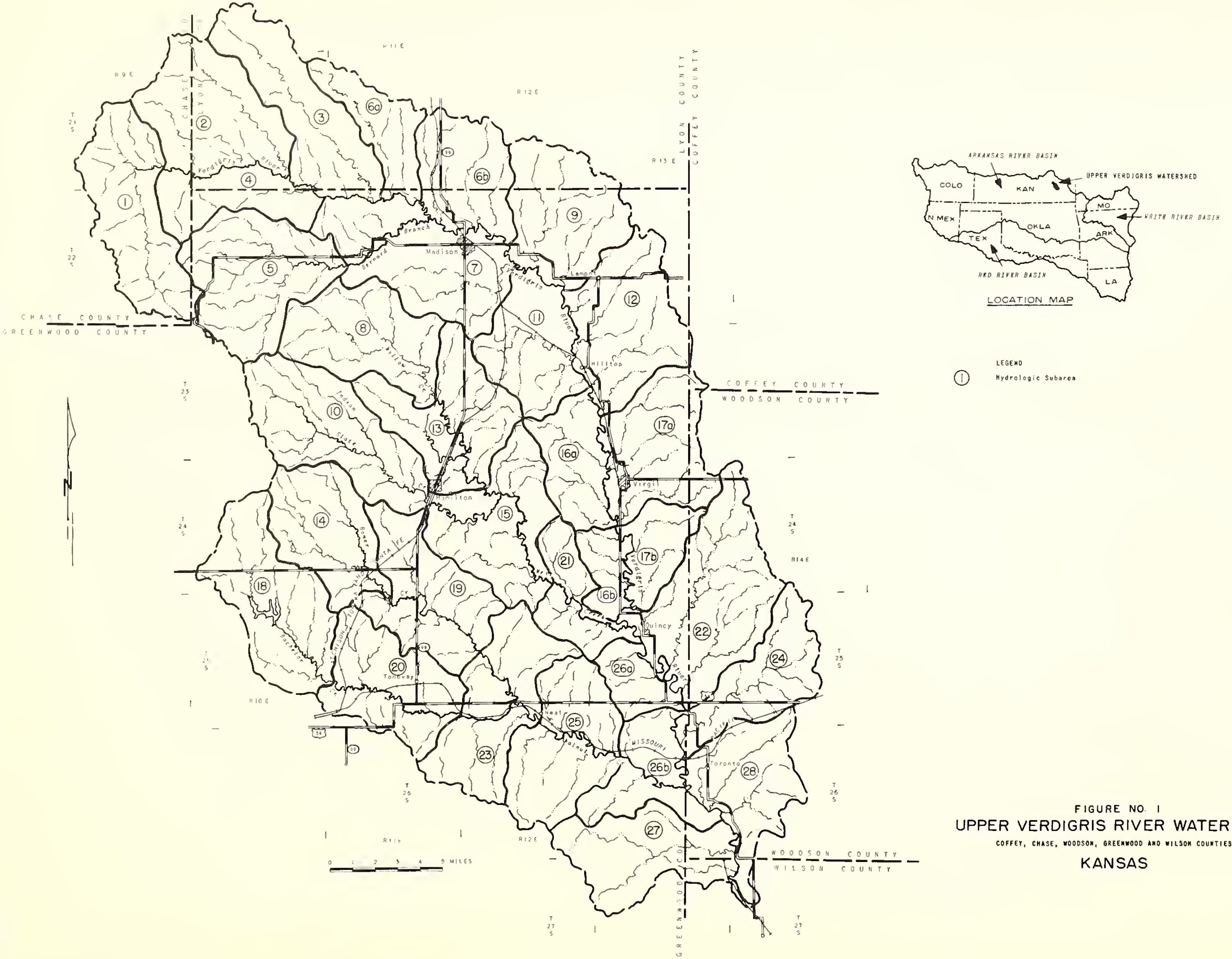


FIGURE NO. 1

UPPER VERDIGRIS RIVER WATERSHED

COFFEY, CHASE, WOODSON, GREENWOOD AND WILSON COUNTIES

KANSAS

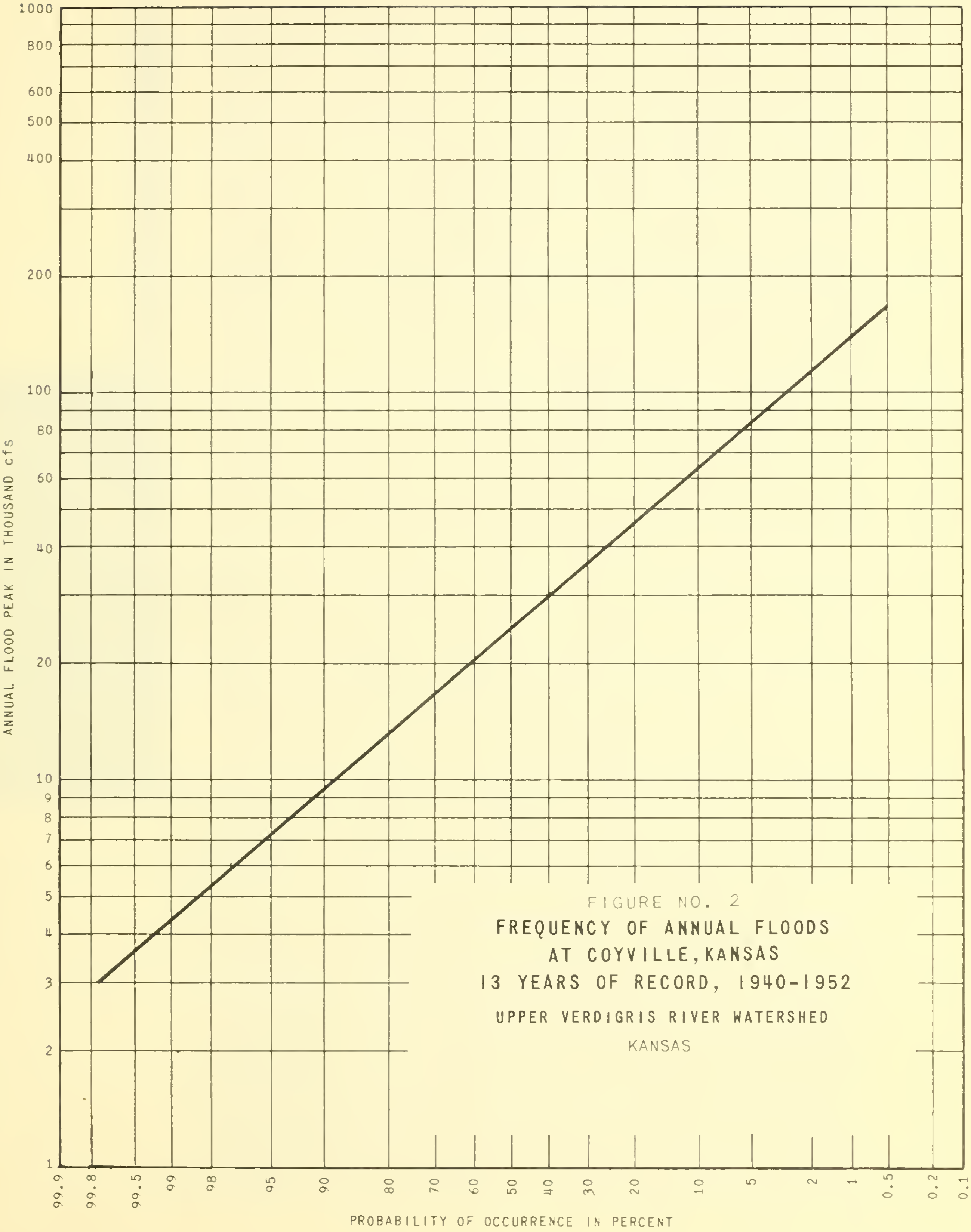


FIGURE NO. 2

FREQUENCY OF ANNUAL FLOODS
AT COYVILLE, KANSAS
13 YEARS OF RECORD, 1940-1952

UPPER VERDIGRIS RIVER WATERSHED

KANSAS

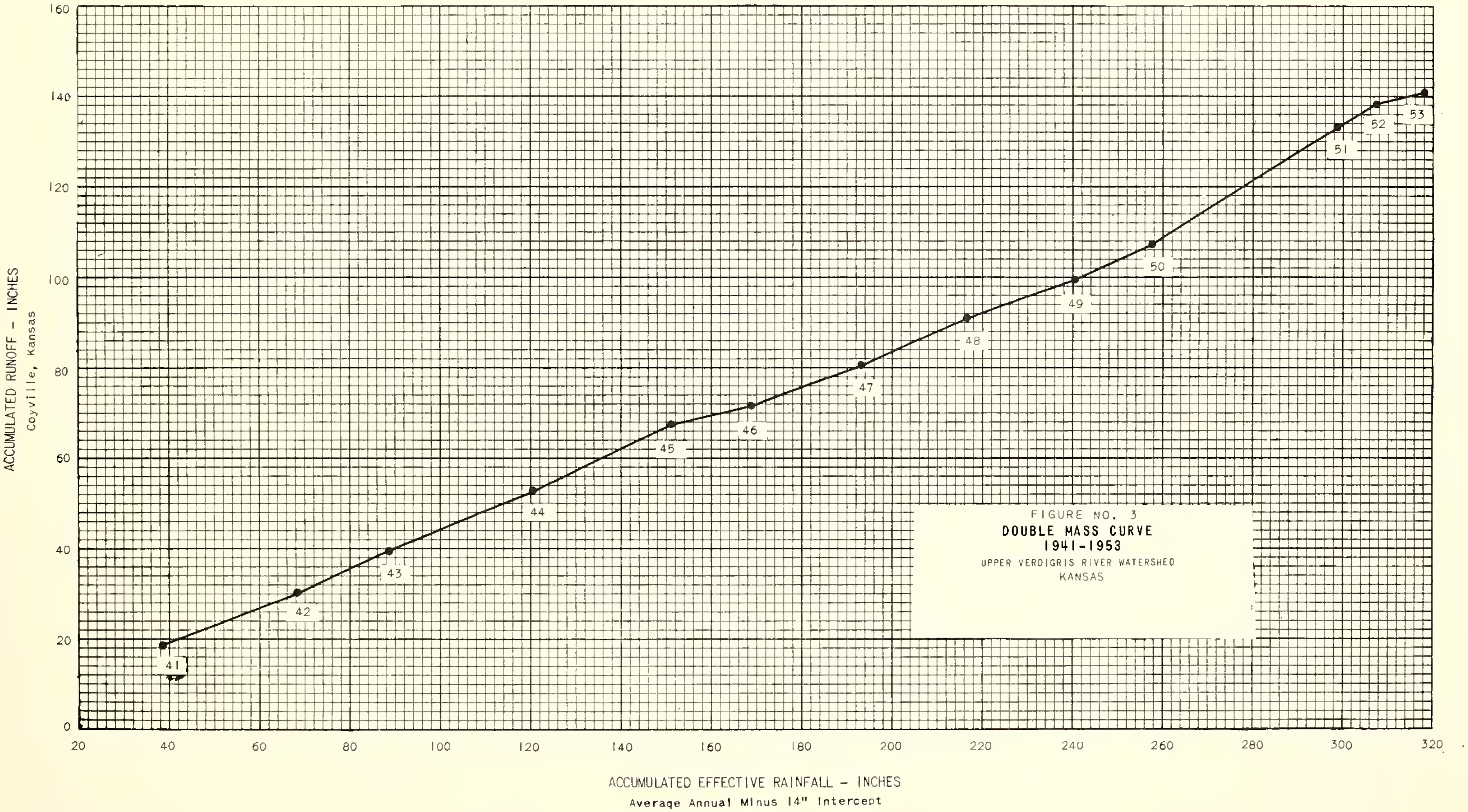


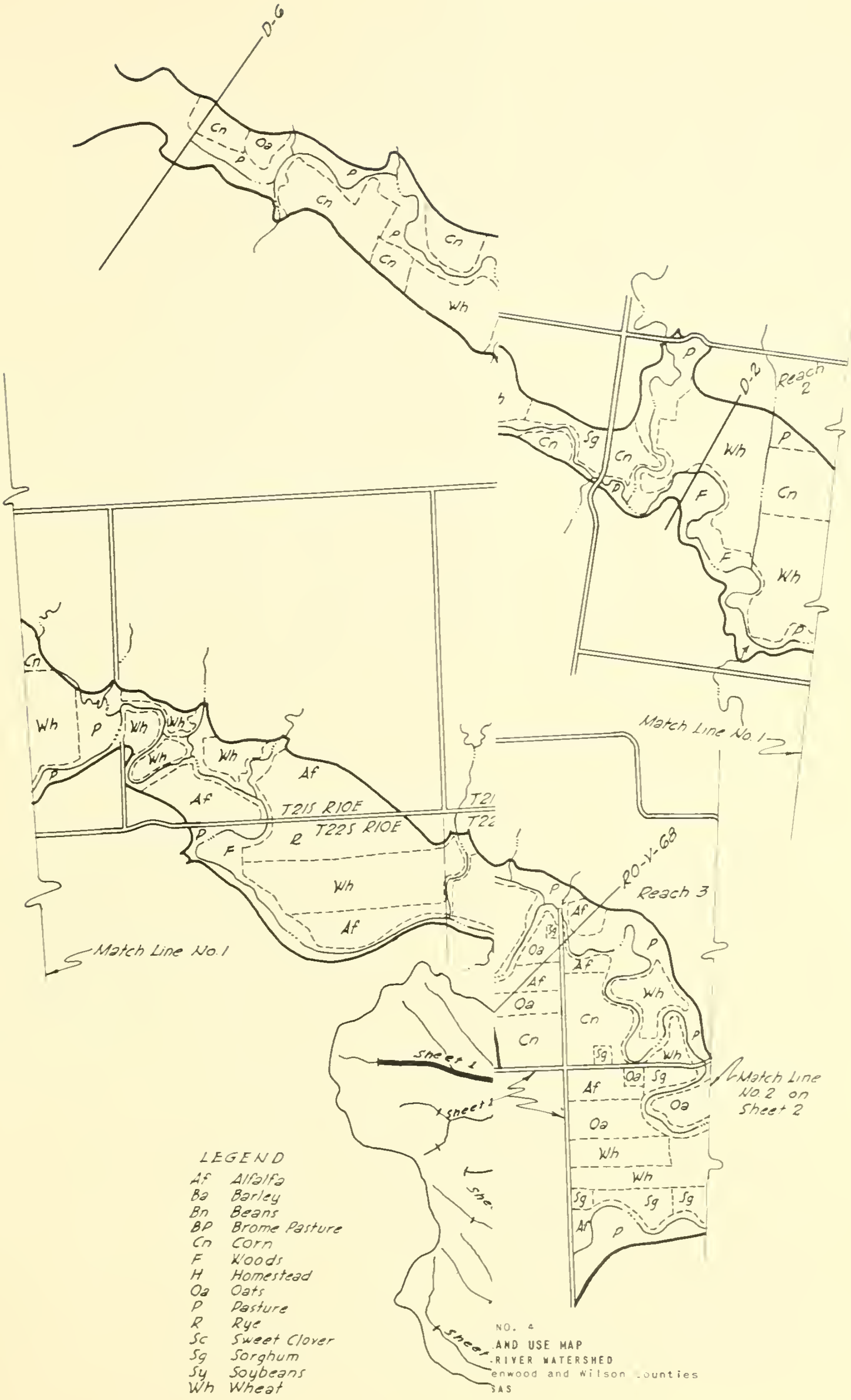
FIGURE NO. 3

DOUBLE MASS CURVE

1941-1953

UPPER VERDIGRIS RIVER WATERSHED

KANSAS



NO. 4
AND USE MAP
RIVER WATERSHED
enwood and Wilson Counties
SAS

UPPER VE

Sheet 1 of 10

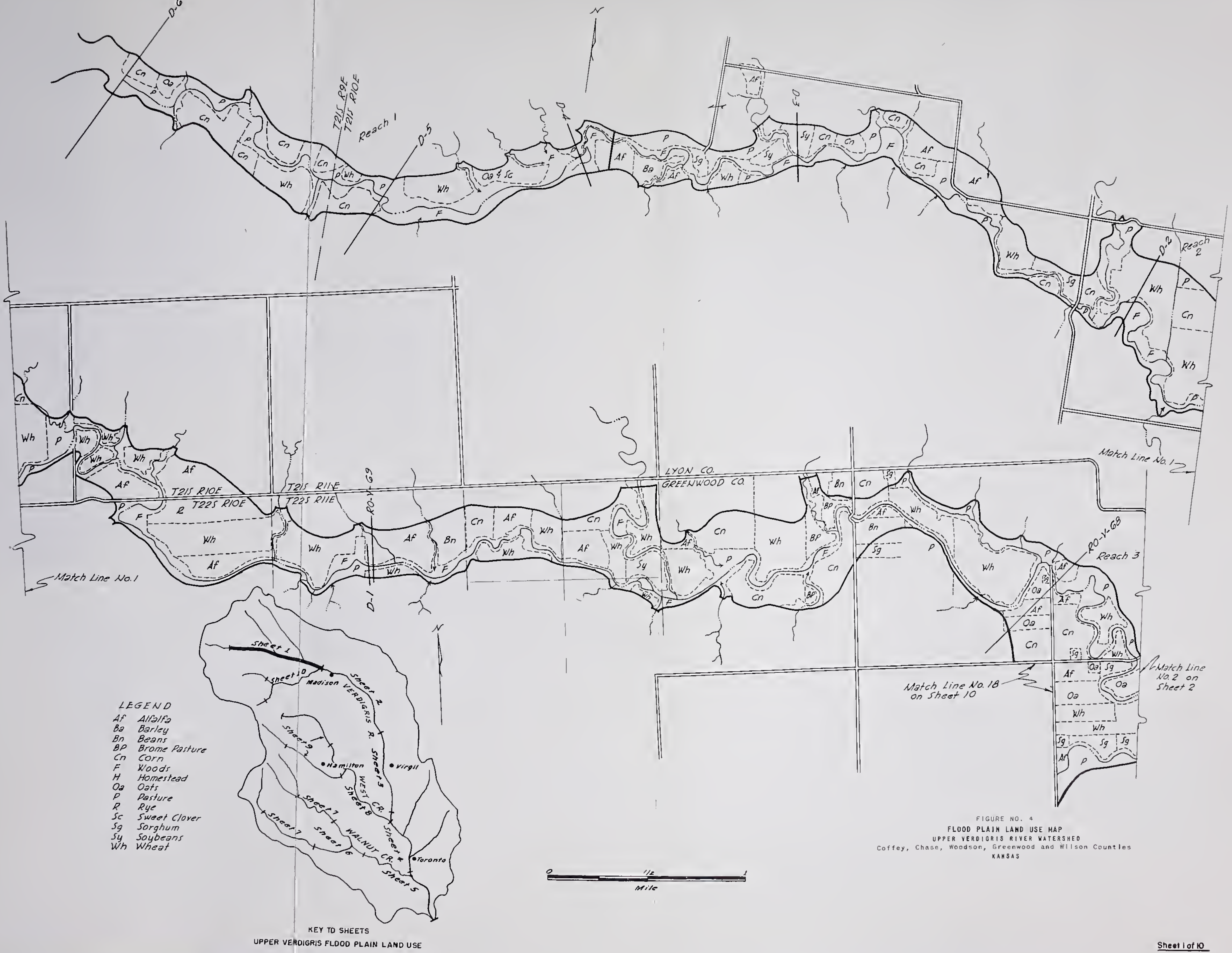
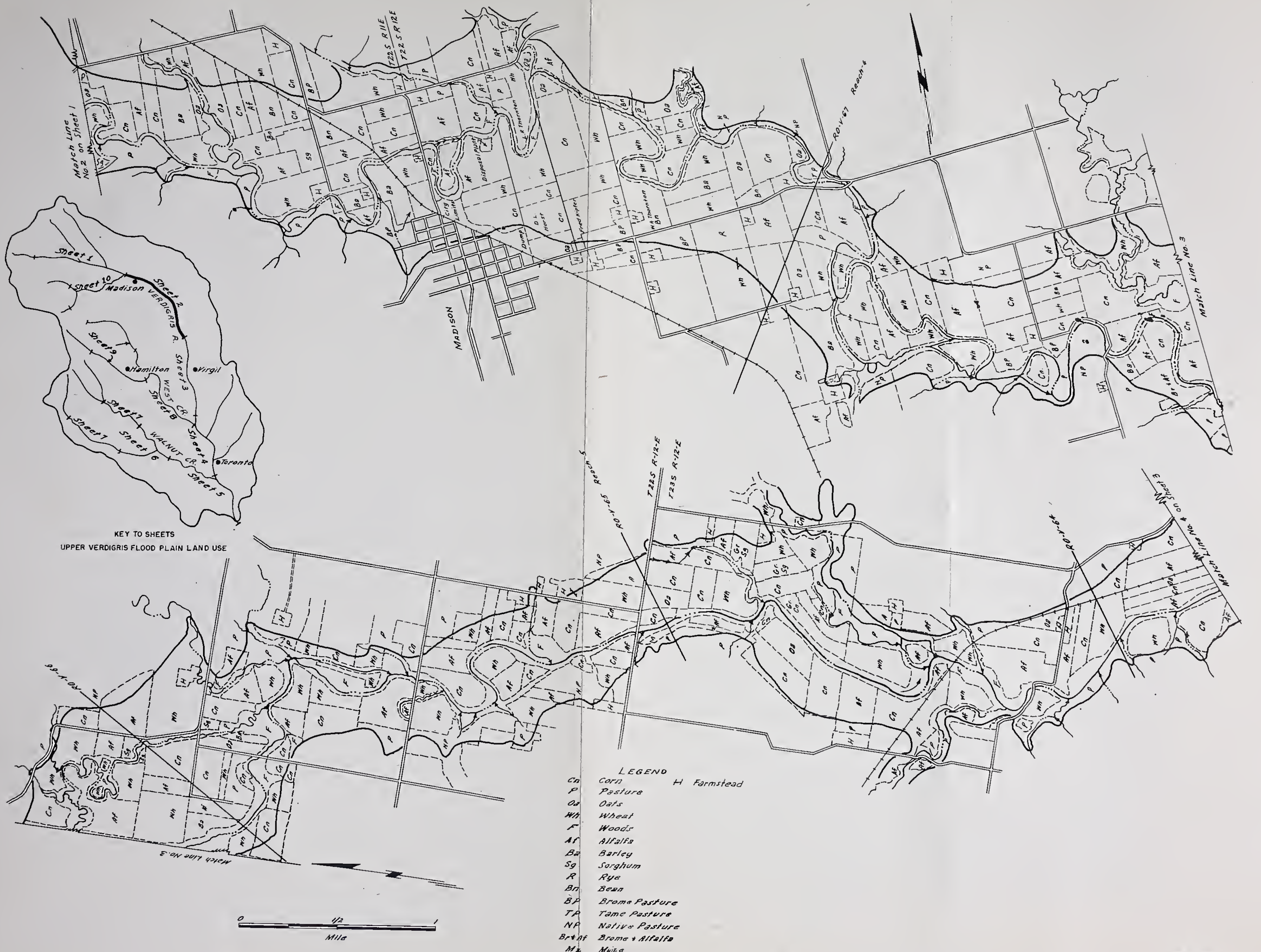


FIGURE NO. 4
FLOOD PLAIN LAND USE MAP
UPPER VERDIGRIS RIVER WATERSHED
Coffey, Chase, Woodson, Greenwood and Wilson Counties
KANSAS

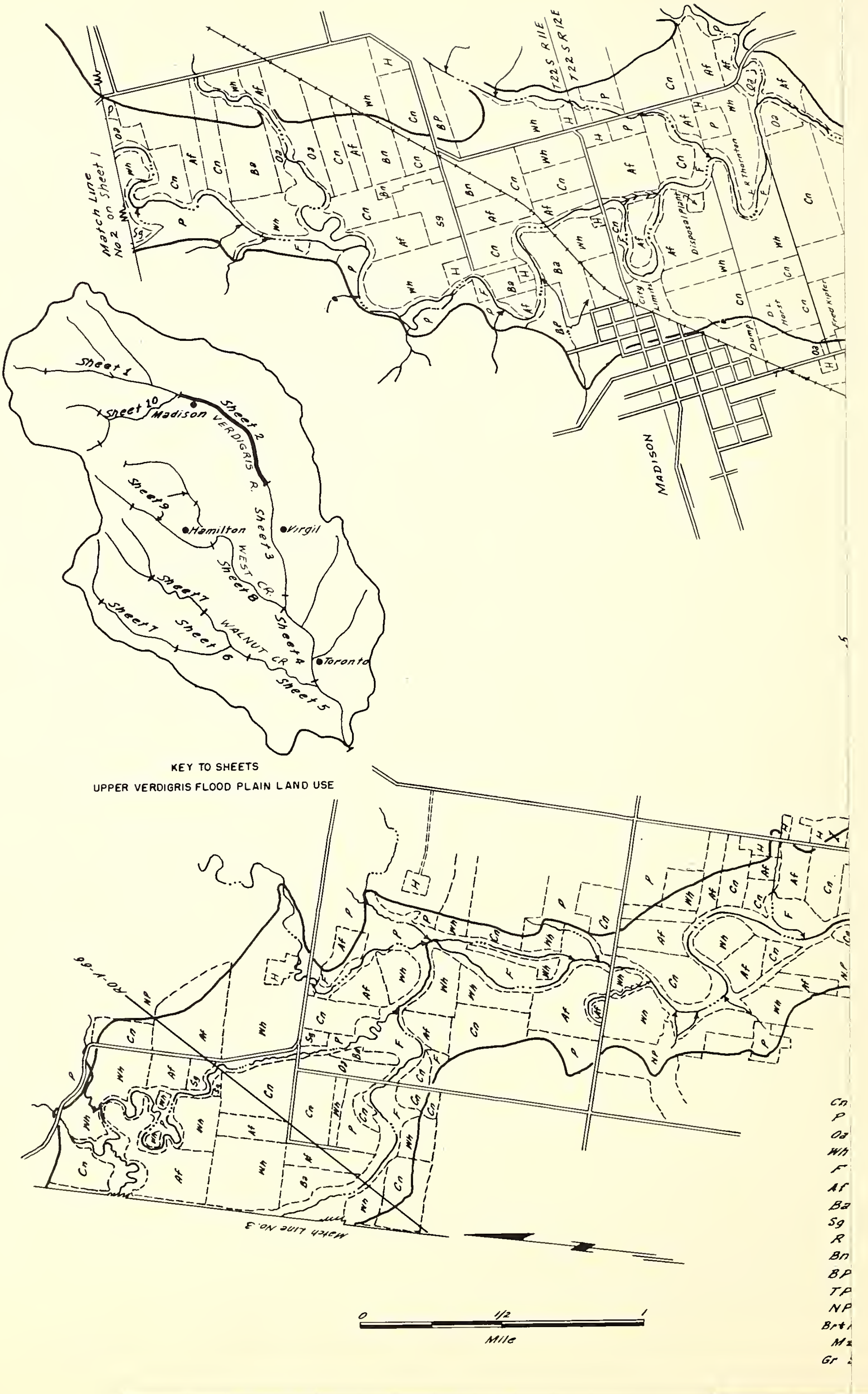
Sheet 1 of 10



LEGEND

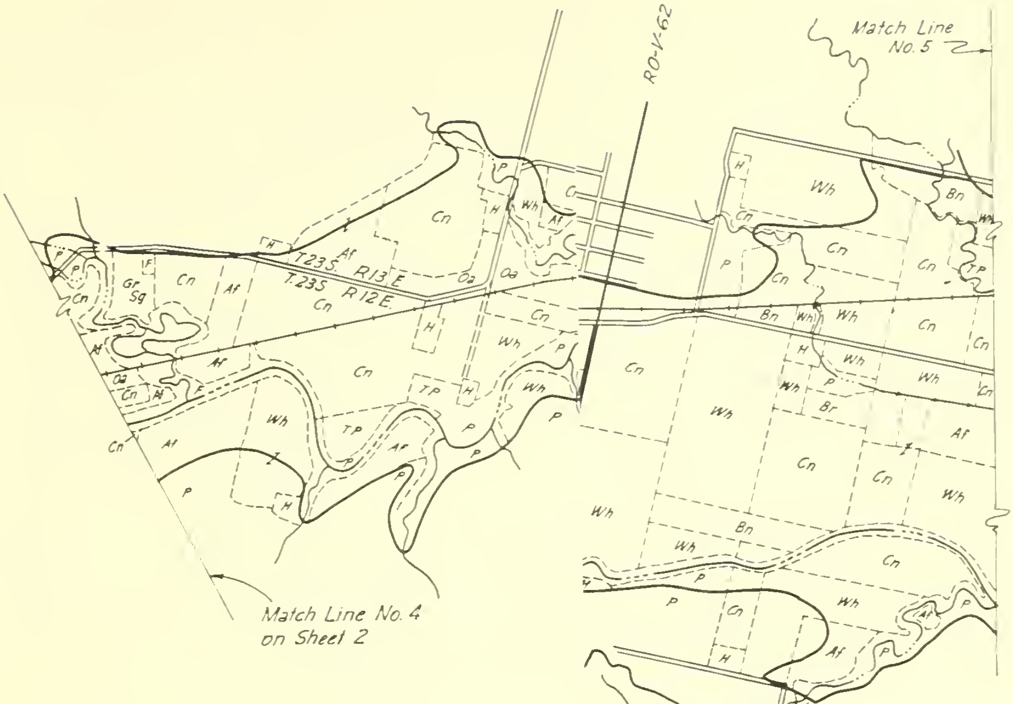
Cn	Corn
H	Farmstead
P	Pasture
Oa	Oats
Wh	Wheat
F	Woods
Af	Alfalfa
Ba	Barley
Sg	Sorghum
R	Rye
Bn	Bean
BP	Brome Pasture
TP	Tame Pasture
NP	Native Pasture
Br+Af	Brome + Alfalfa
Mz	Maize
Gr Sg	Grain Sorghum

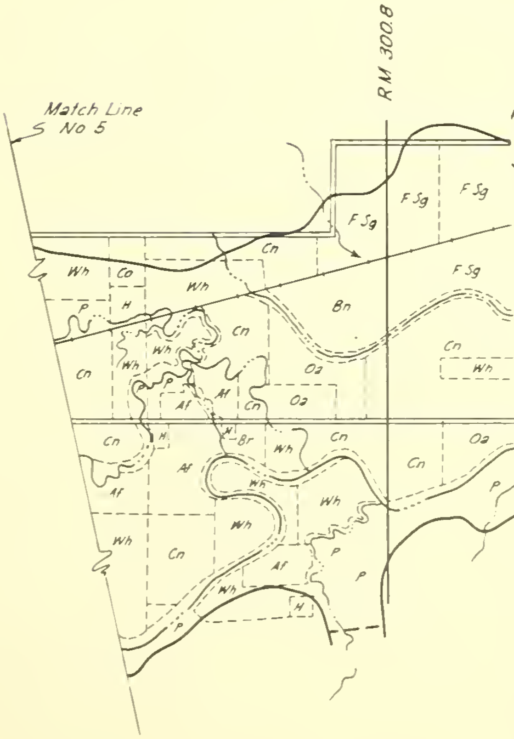
Sheet 2 of 10

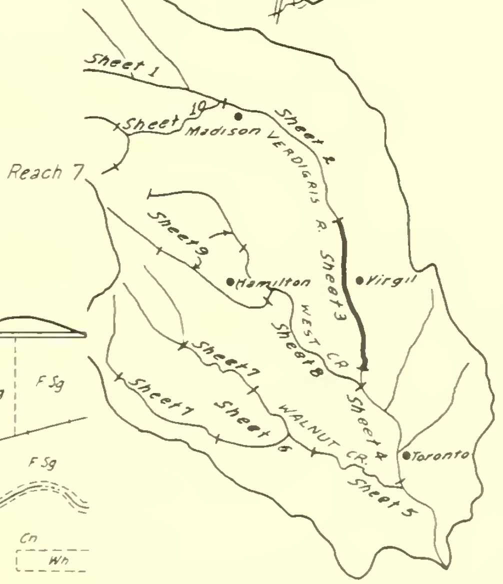


KEY TO SHEETS

UPPER VERDIGRIS FLOOD PLAIN LAND USE







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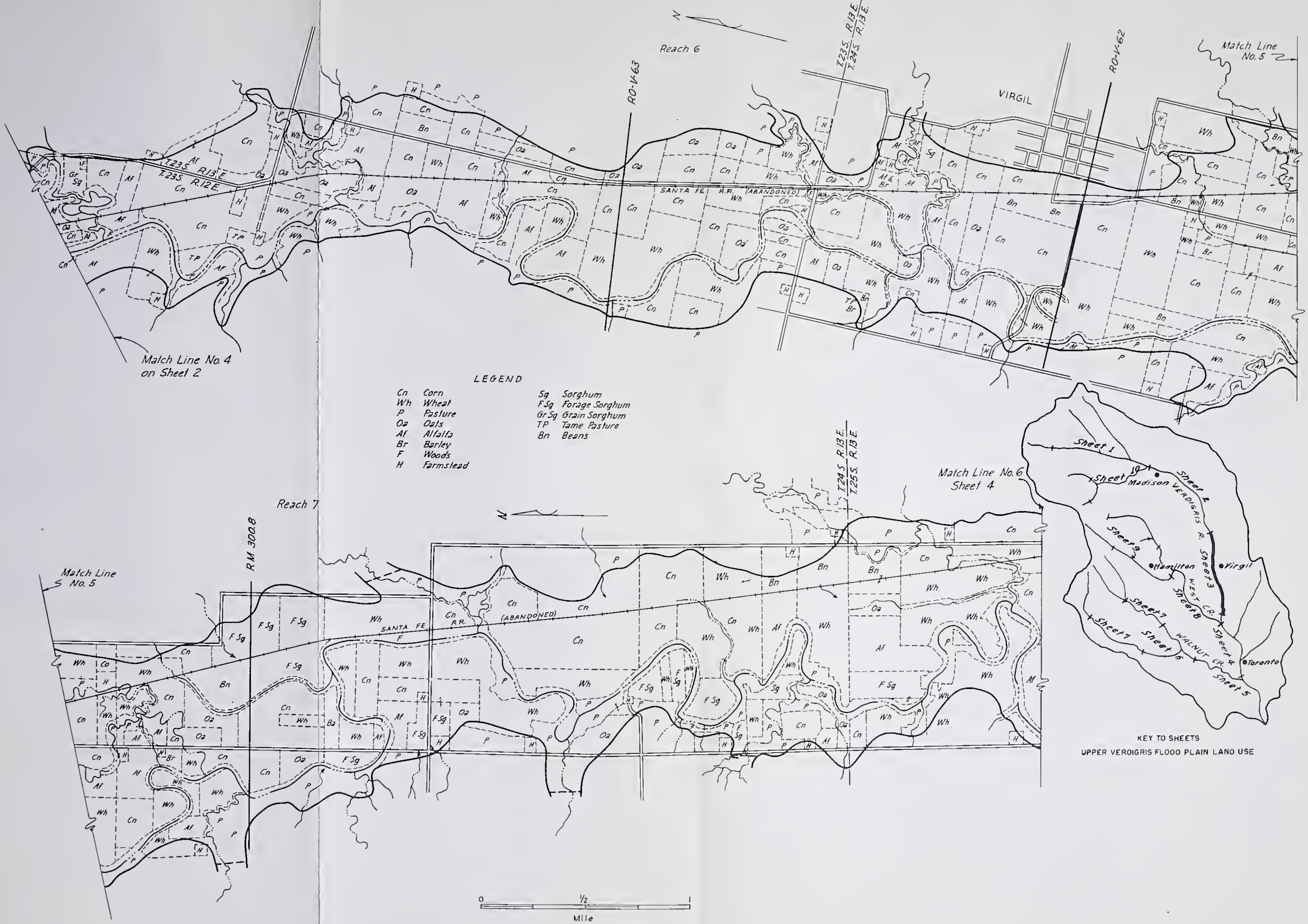
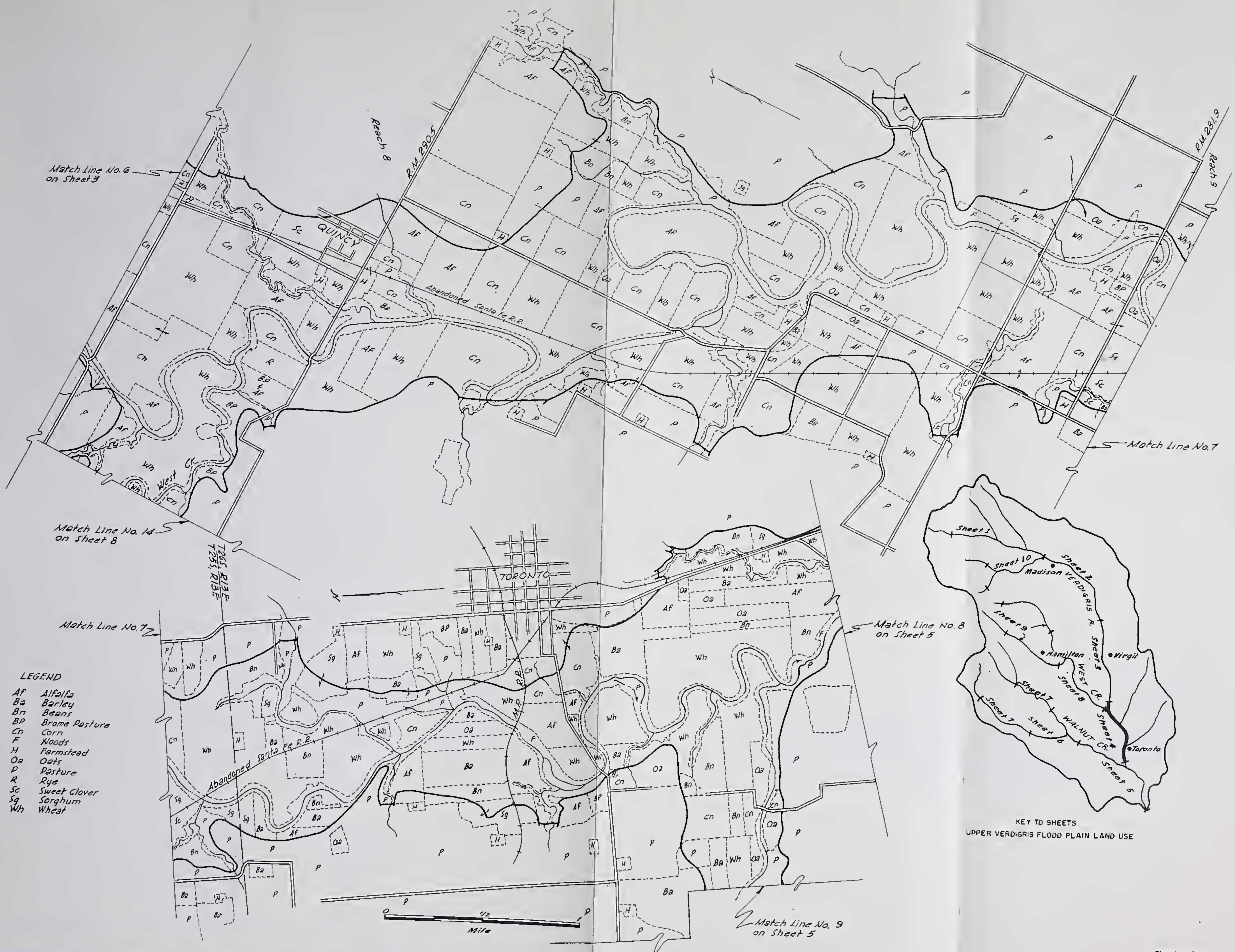
UPPER VERDIGRIS FLOOD PLAIN LAND USE



KEY TO SHEETS
UPPER VERDIGRIS FLOOD PLAIN LAND USE

Sheet 3 of 10



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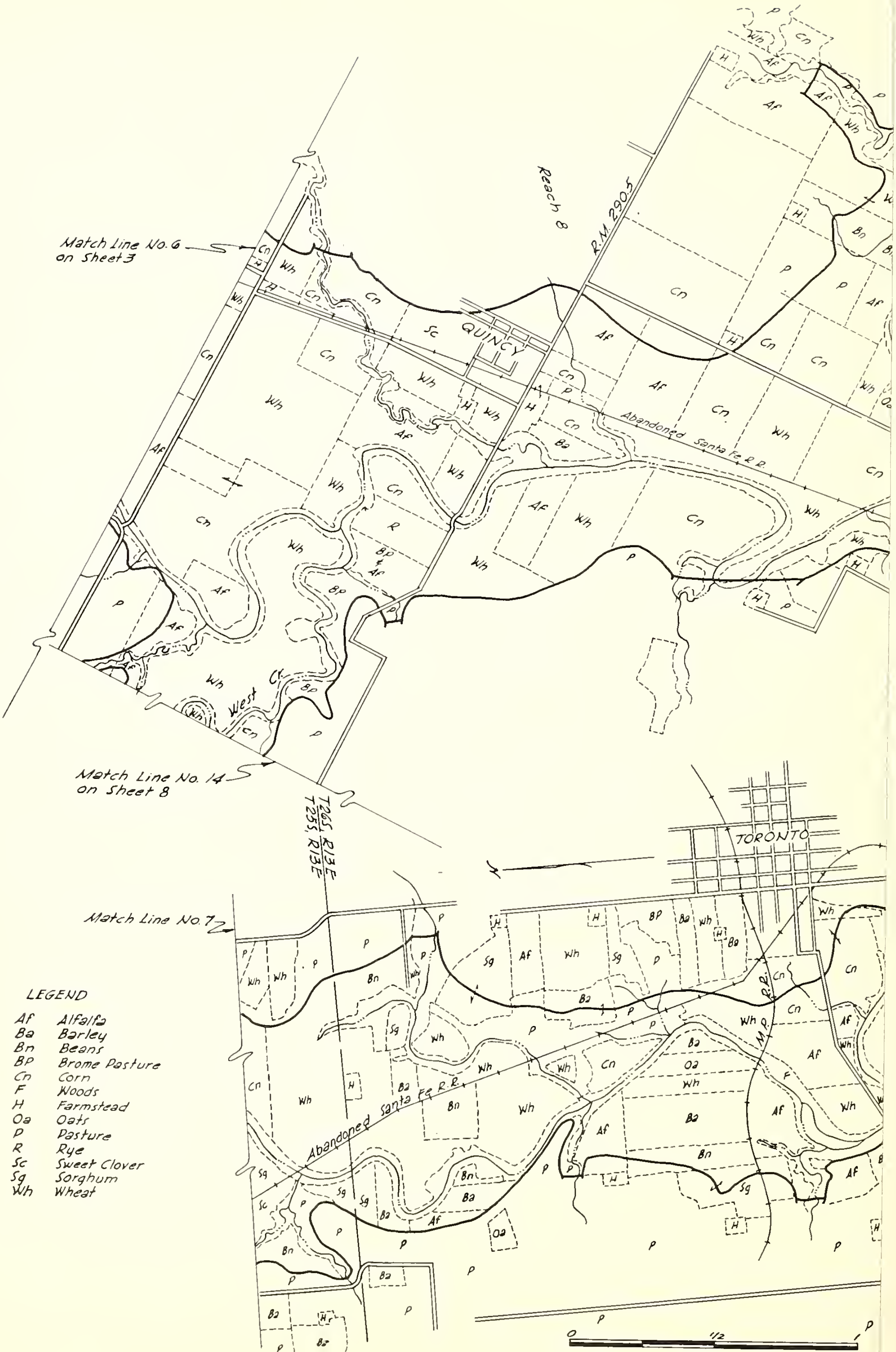
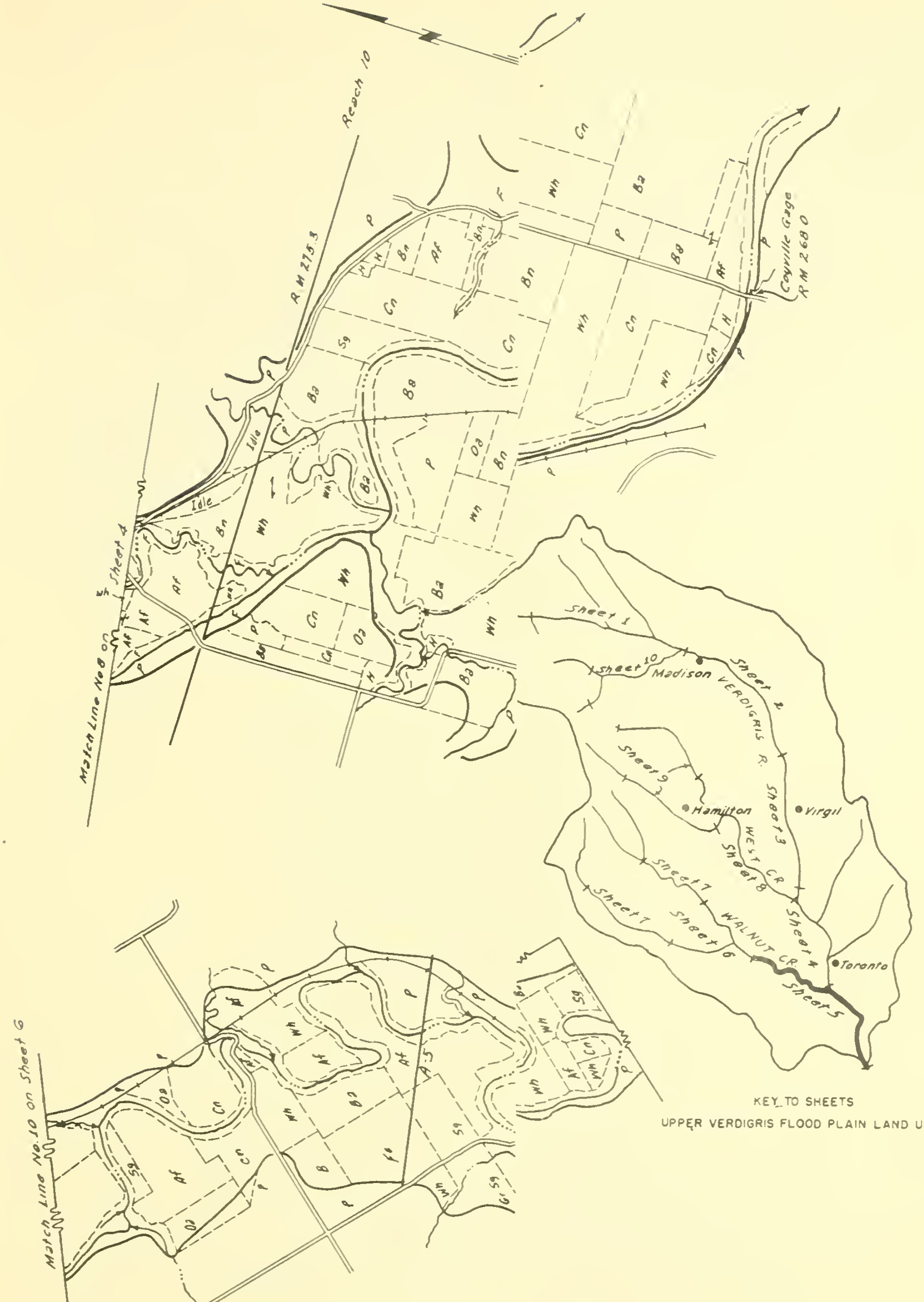
UPPER VERDIGRIS FLOOD PLAIN LAND USE


Match Line No. 6 on Sheet 3
Reach 8
R.M. 290.5
QUINCY
Abandoned Santa Fe R.R.
West Cr.
Match Line No. 14 on Sheet 8
T26S, R13E
T25S, R13E
TORONTO
Match Line No. 7
M.P. R.R.
LEGEND
Af Alfalfa
Ba Barley
Bn Beans
BP Brome Pasture
Cn Corn
F Woods
H Farmstead
Oa Oats
P Pasture
R Rye
Sc Sweet Clover
Sg Sorghum
Wh Wheat
0
1/2
1
Mile

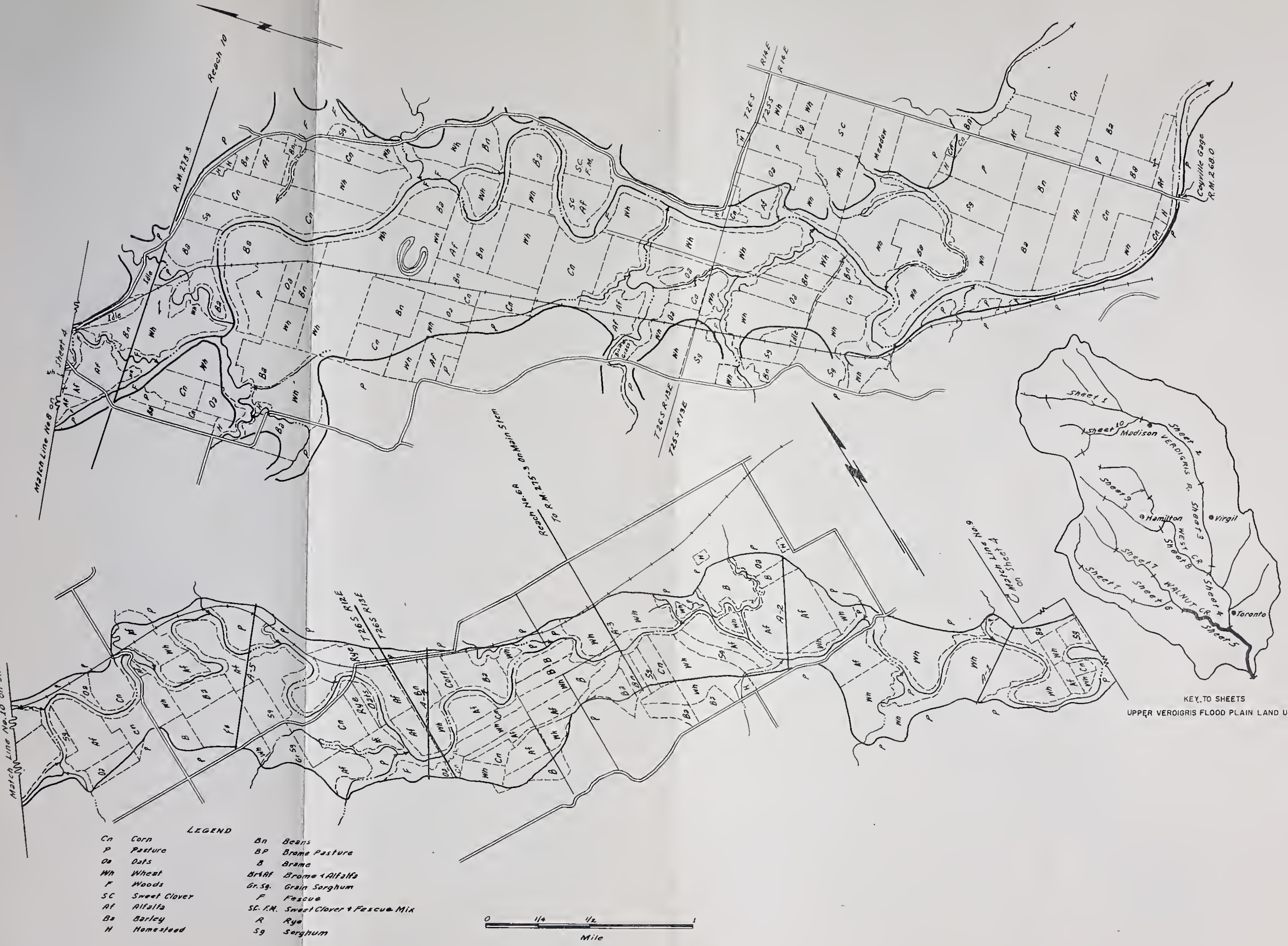


KEY TO SHEETS
UPPER VERDIGRIS FLOOD PLAIN LAND USE

LEGEND

Cn	Corn	Bn	Beai
P	Pasture	BP	Brom
Oa	Oats	B	Brom
Wh	Wheat	Br+Af	Bro.
F	Woods	Gr Sg	Grai
SC	Sweet Clover	F	Fes
Af	Alfalfa	SC F.M.	Swe
Ba	Barley	R	Rye
H	Homestead	Sg	Sorg

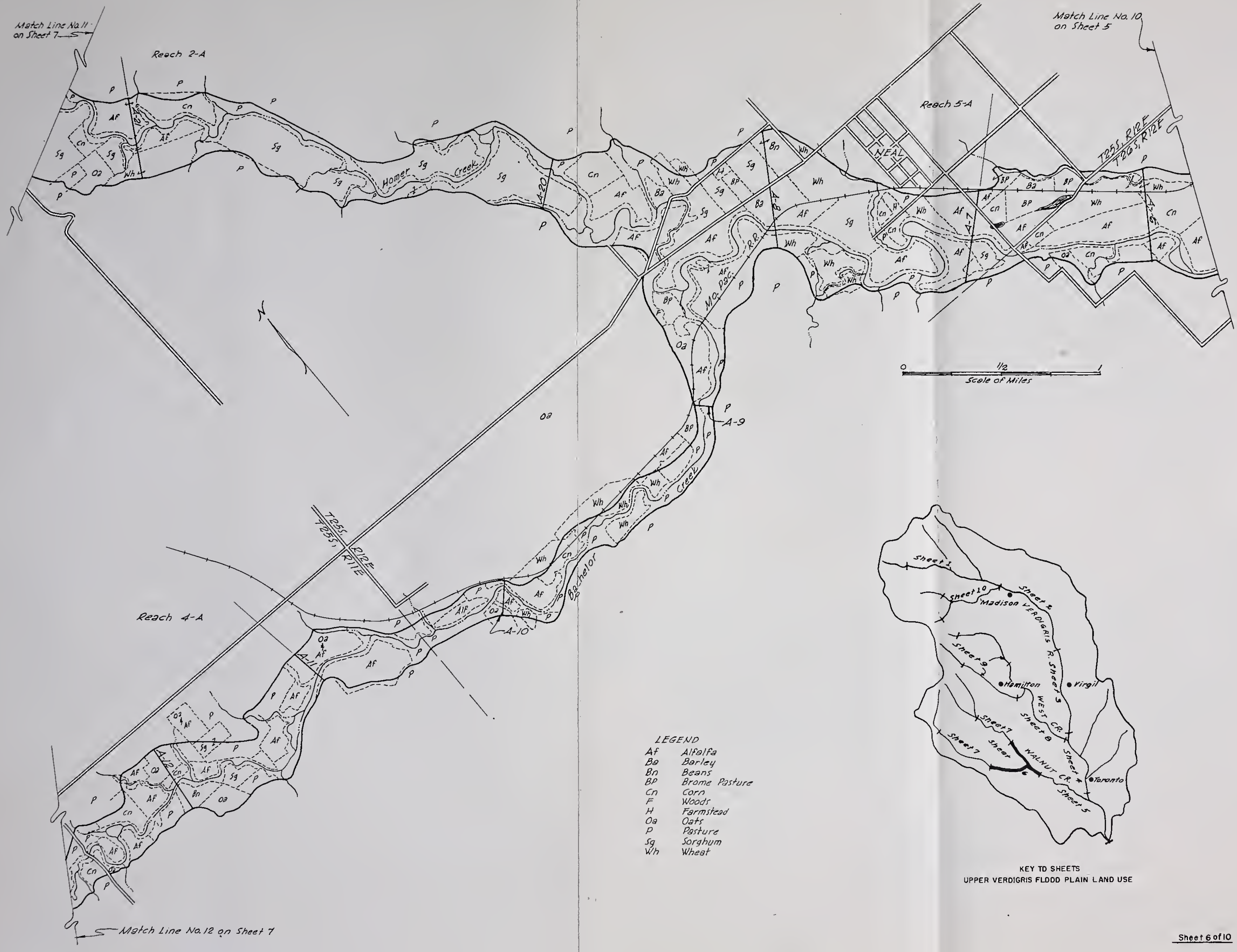
Sheet 5 of 10



KEY TO SHEETS
UPPER VERDIGRIS FLOOD PLAIN LAND USE

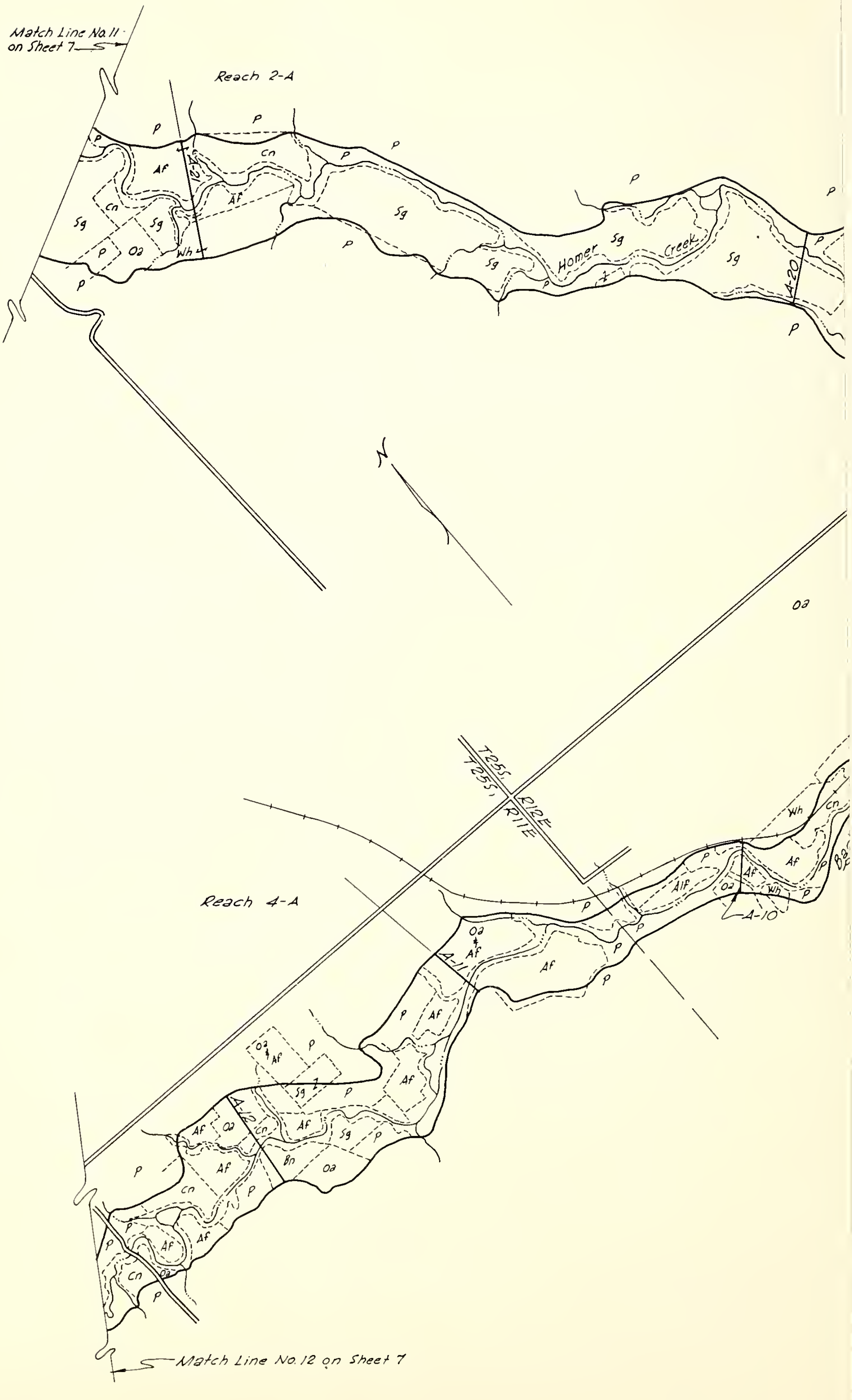
LEGEND

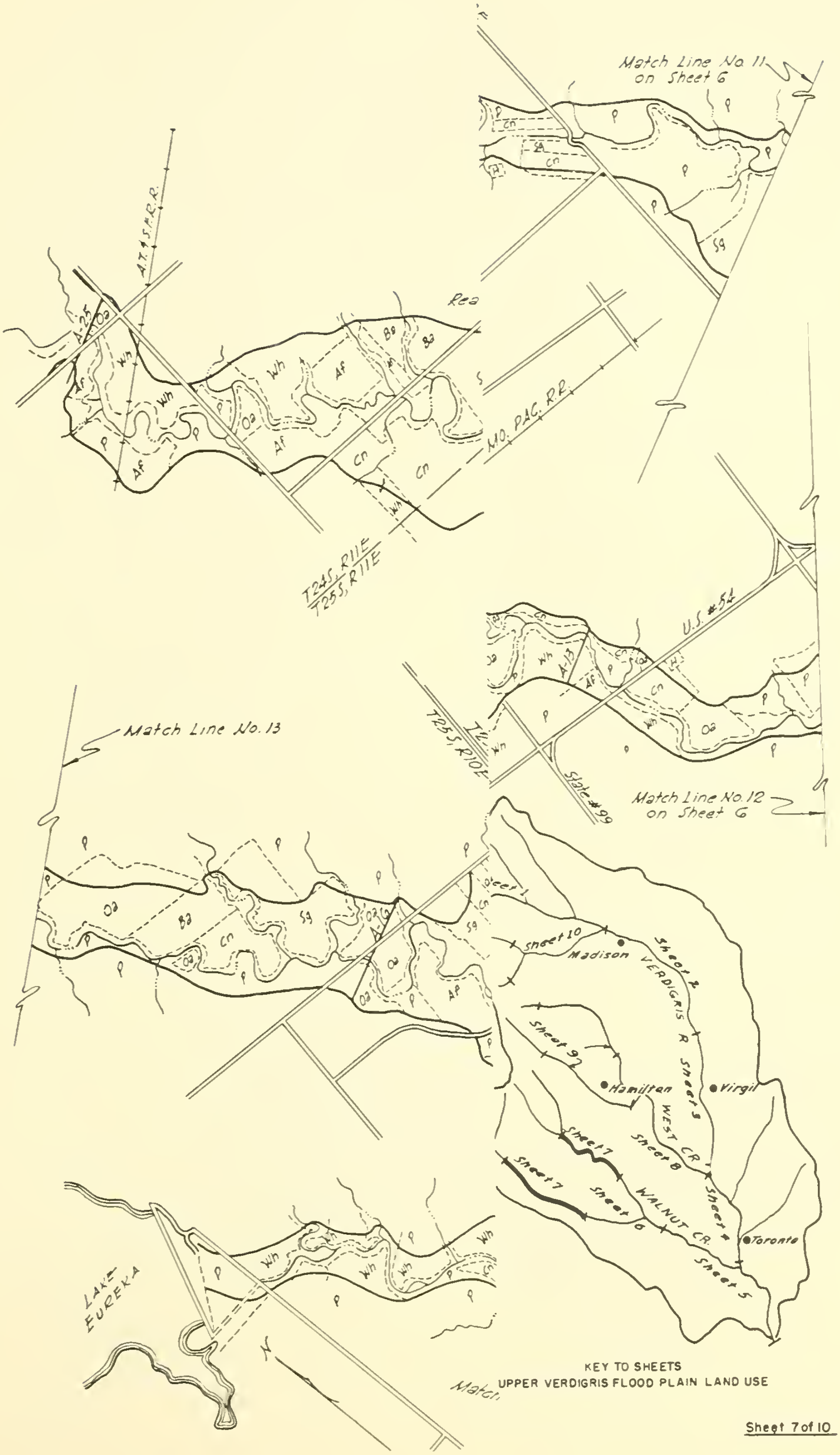
Cn	Corn	Bn	Beans
P	Pasture	BP	Brome Pasture
Oa	Oats	B	Brome
Wh	Wheat	Br&Af	Brome & Alfalfa
F	Woods	Gr. Sg.	Grain Sorghum
SC	Sweet Clover	F	Fescue
Af	Alfalfa	SC. F.M.	Sweet Clover & Fescue Mix
Ba	Barley	R	Rye
H	Homestead	Sg	Sorghum



KEY TO SHEETS
UPPER VERDIGRIS FLOOD PLAIN LAND USE

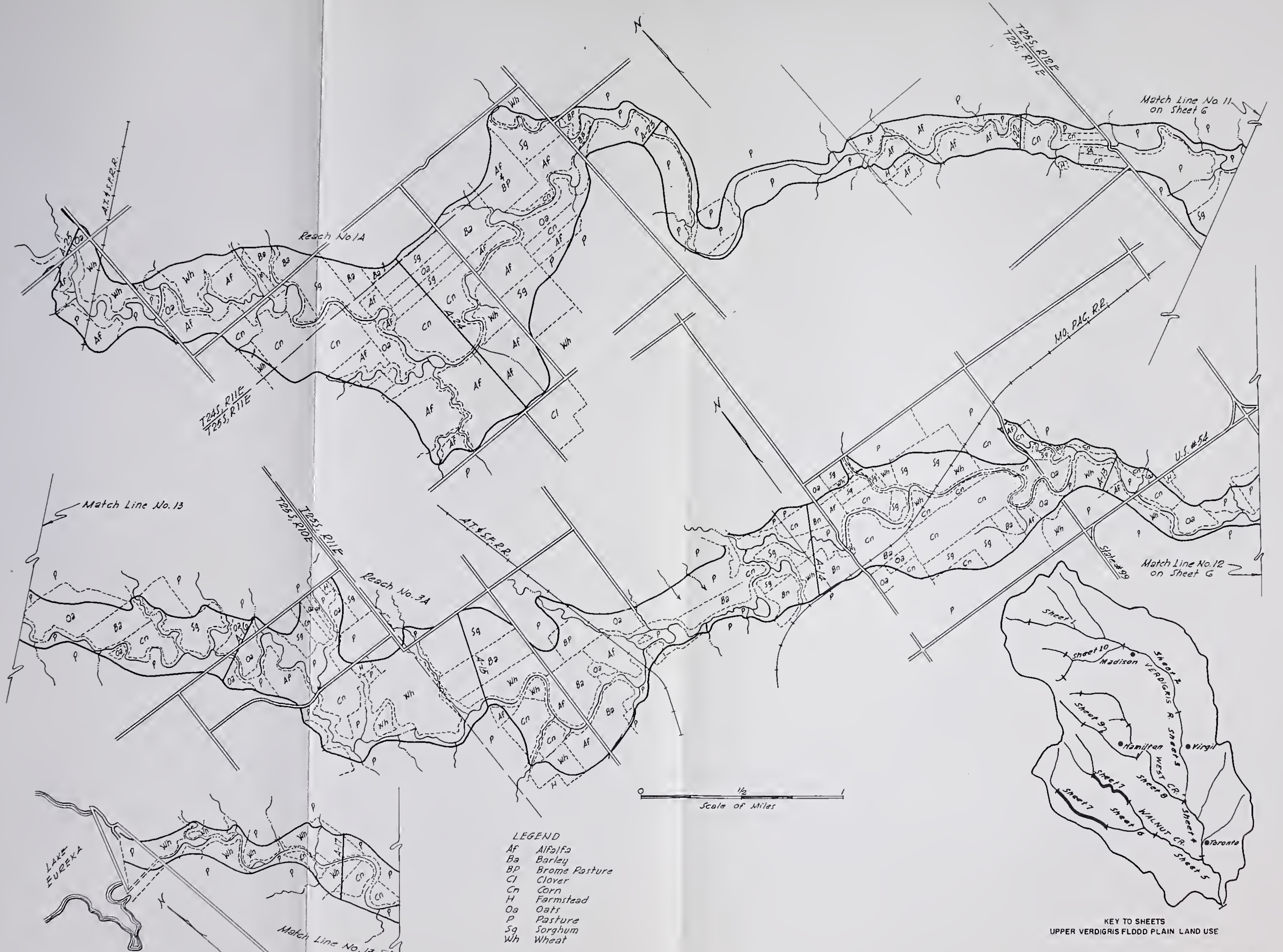
Sheet 6 of 10


Match Line No. 11 on Sheet 7
Reach 2-A
A-21
Homer Creek
A-20
P
Af
Cn
Sg
Oa
Wh
N
T25S, R12E
T25S, R11E
Reach 4-A
A-10
A-11
A-12
Oa & Af
Bn
Match Line No. 12 on Sheet 7



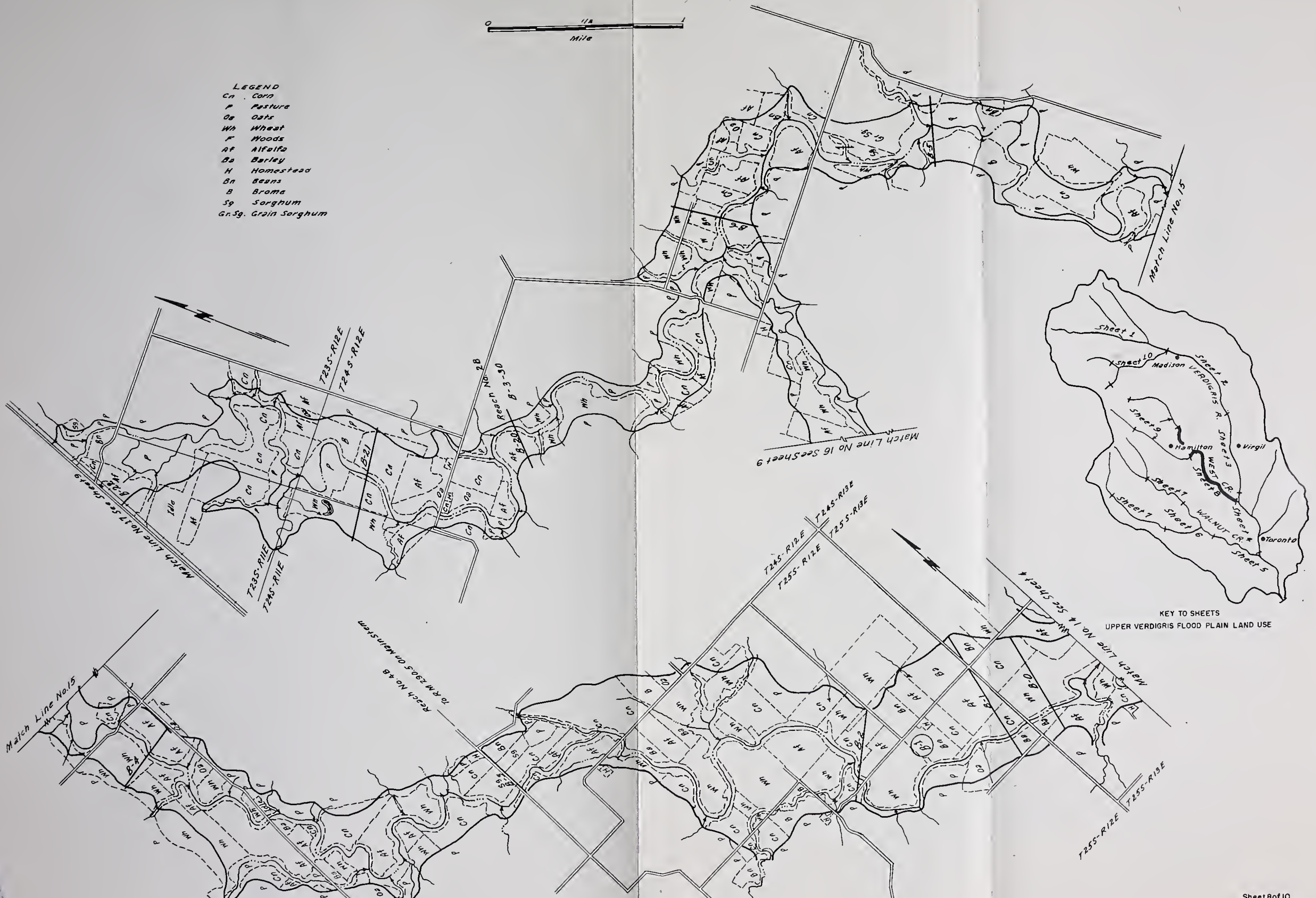
KEY TO SHEETS
UPPER VERDIGRIS FLOOD PLAIN LAND USE

Sheet 7 of 10

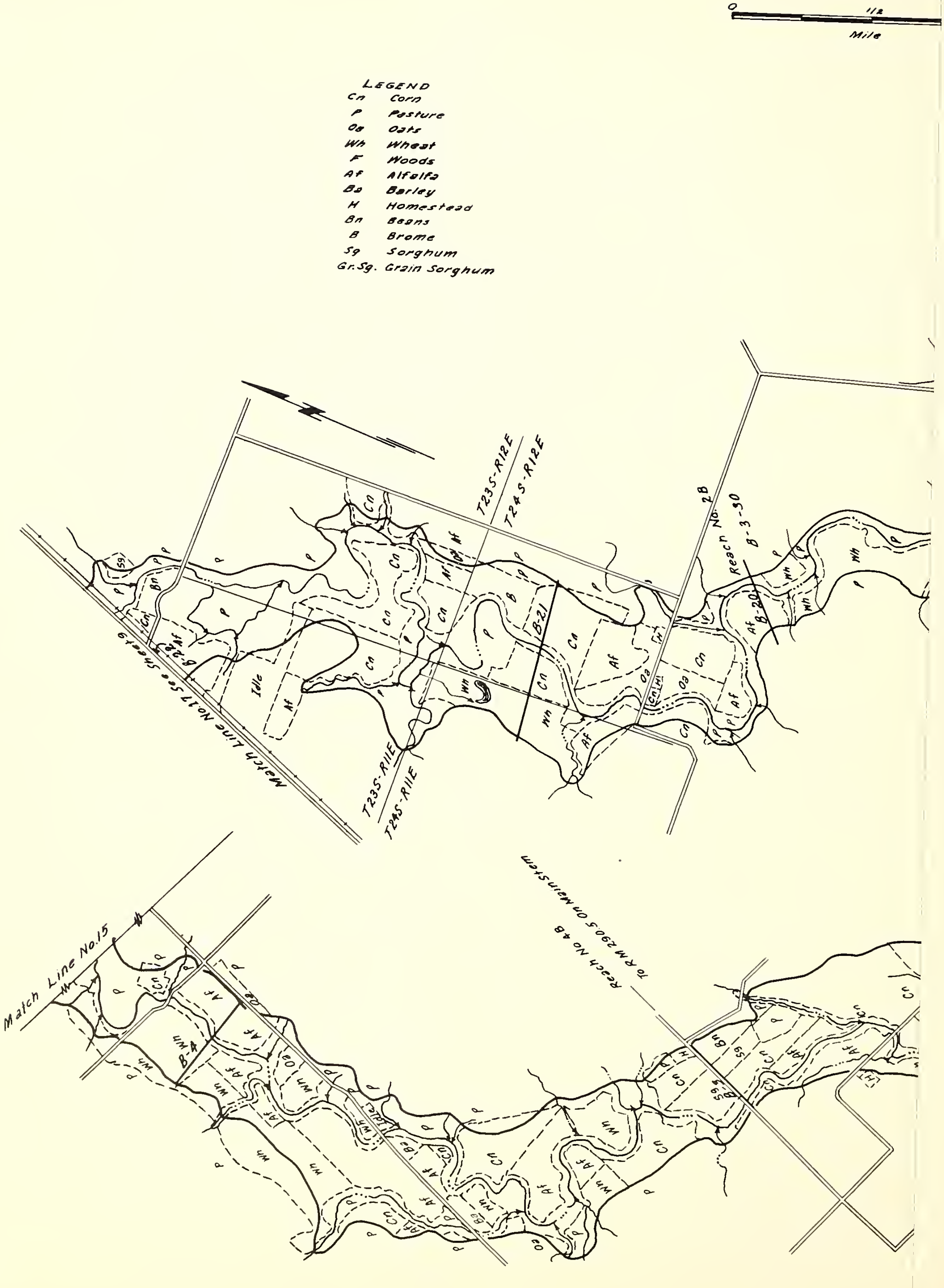


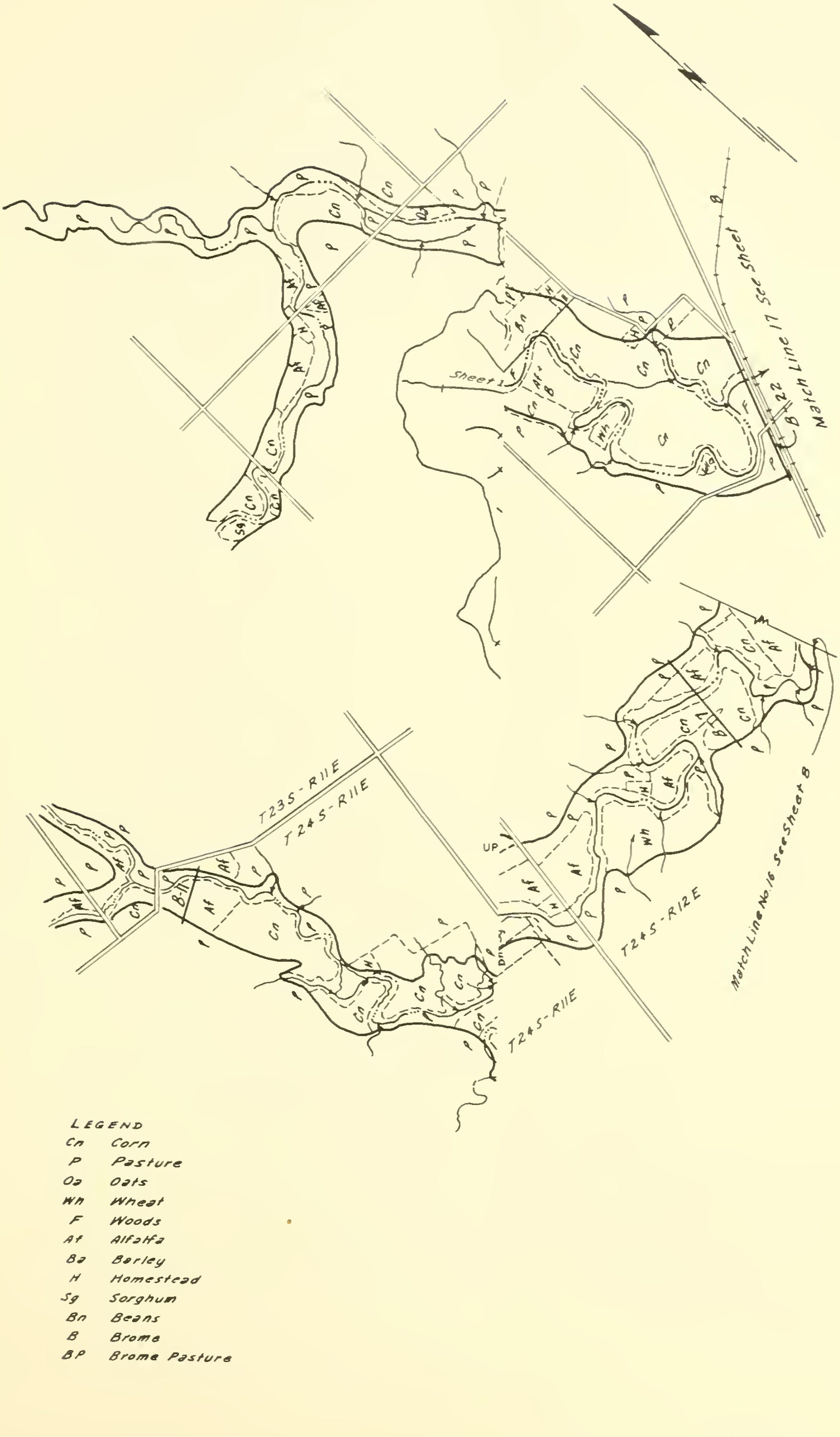
KEY TO SHEETS
UPPER VERDIGRIS FLOOD PLAIN LAND USE

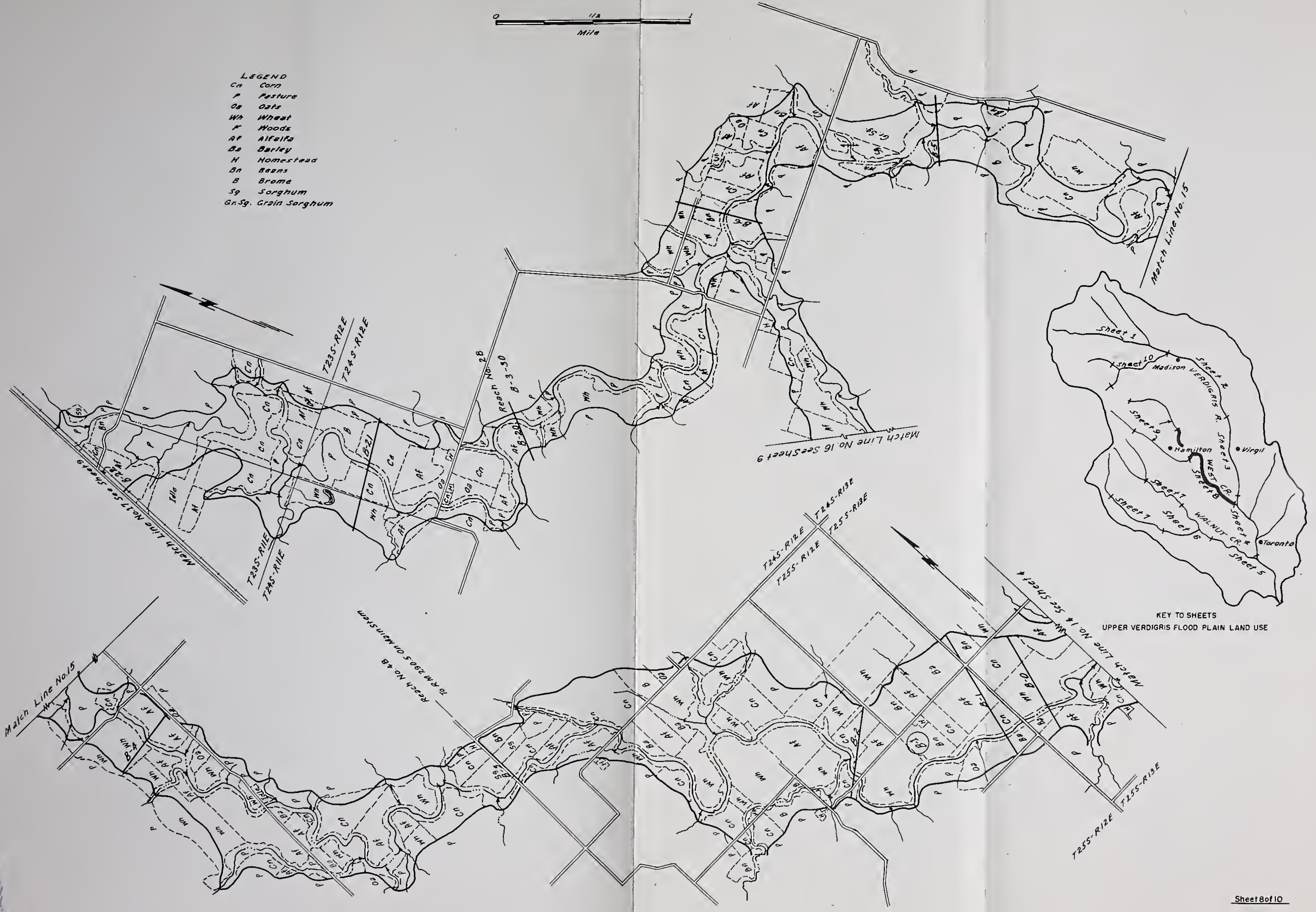
Sheet 7 of 10


0 1/2 1
Mile
LEGEND
Cn Corn
P Pasture
Oa Oats
Wh Wheat
F Woods
Af Alfalfa
Ba Barley
H Homestead
Bn Beans
B Brome
Sg Sorghum
Gr.Sg. Grain Sorghum
T23S-R12E
T24S-R12E
T23S-R11E
T24S-R11E
Reach No. 2B
B-3-30
B-20
B-21
B-22
Match Line No.17 See Sheet 9
Match Line No 16 See Sheet 9
Match Line No. 15
Reach No 4B
To R.M. 290.5 on Mainstem
T24S-R12E
T25S-R12E
T24S-R13E
T25S-R13E
Match Line No. 14 See Sheet 4
B-4
B-5
B-6
B-7
Sheet 1
Sheet 10
Madison
Sheet 2
VERDIGRIS R.
Sheet 9
Sheet 3
Hamilton
Virgil
WEST CR.
Sheet 8
Sheet 7
Sheet 4
Sheet 6
WALNUT CR.
Sheet 5
Toronto
KEY TO SHEETS
UPPER VERDIGRIS FLOOD PLAIN LAND USE

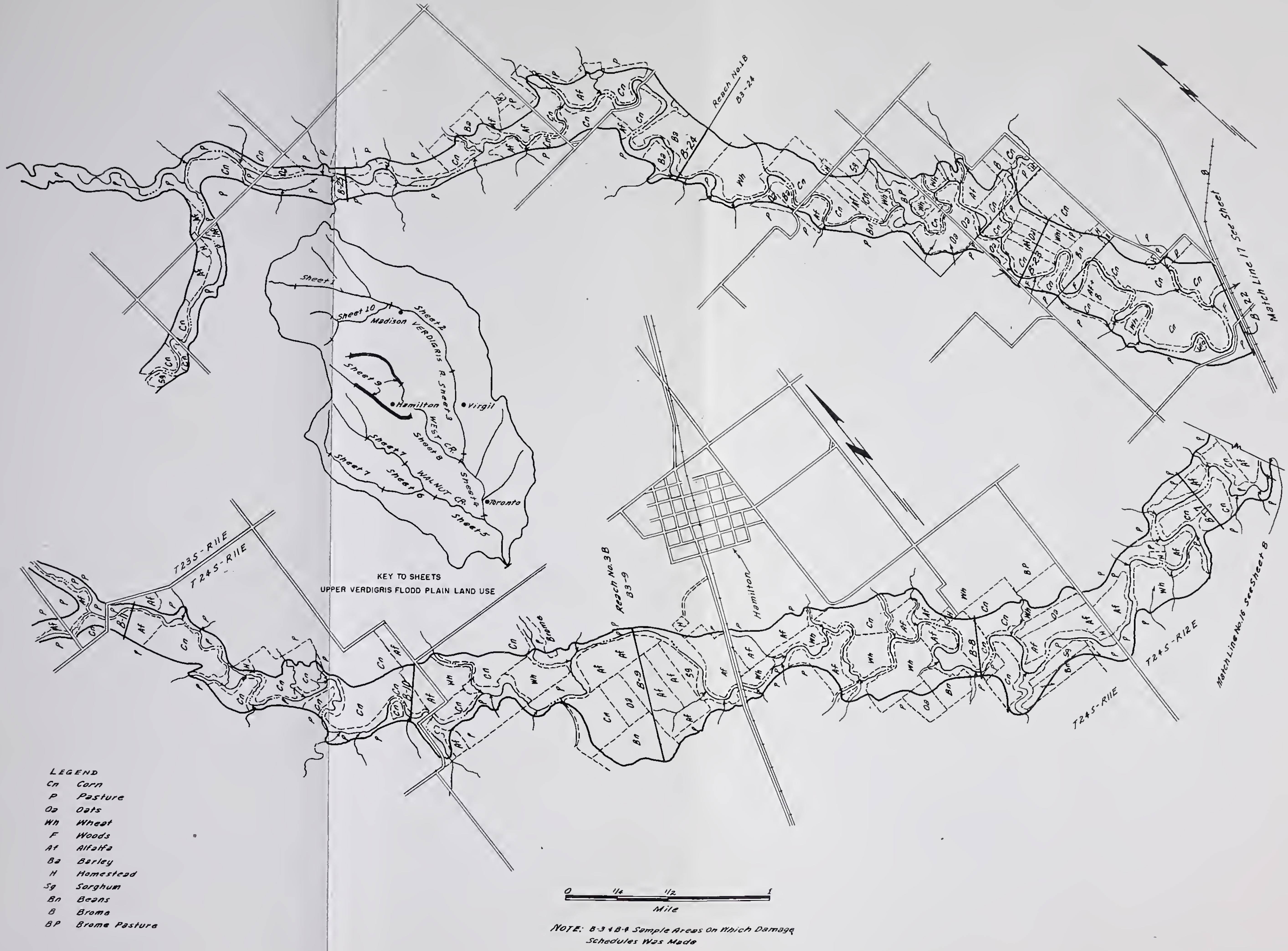
Sheet 8 of 10


0
1/2
Mile
LEGEND
Cn Corn
P Pasture
Oa Oats
Wh Wheat
F Woods
Af Alfalfa
Ba Barley
H Homestead
Bn Beans
B Brome
Sg Sorghum
Gr.Sg. Grain Sorghum
T23S-R12E
T24S-R12E
T23S-R11E
T24S-R11E
Reach No. 2B
B-3-30
B-21
B-20
B-28
Idle
Match Line No.17 See Sheet 6
Match Line No.15
B-4
Reach No 4B
To RM 290.5 on Main Stem


Match Line 17 See Sheet
Match Line No 16 See Sheet 8
T23S-R11E
T24S-R11E
T24S-R12E
T24S-R11E
Sheet 1
UP
B-1
B 22
LEGEND
Cn Corn
P Pasture
Oa Oats
Wh Wheat
F Woods
Af Alfalfa
Ba Barley
H Homestead
Sg Sorghum
Bn Beans
B Brome
BP Brome Pasture

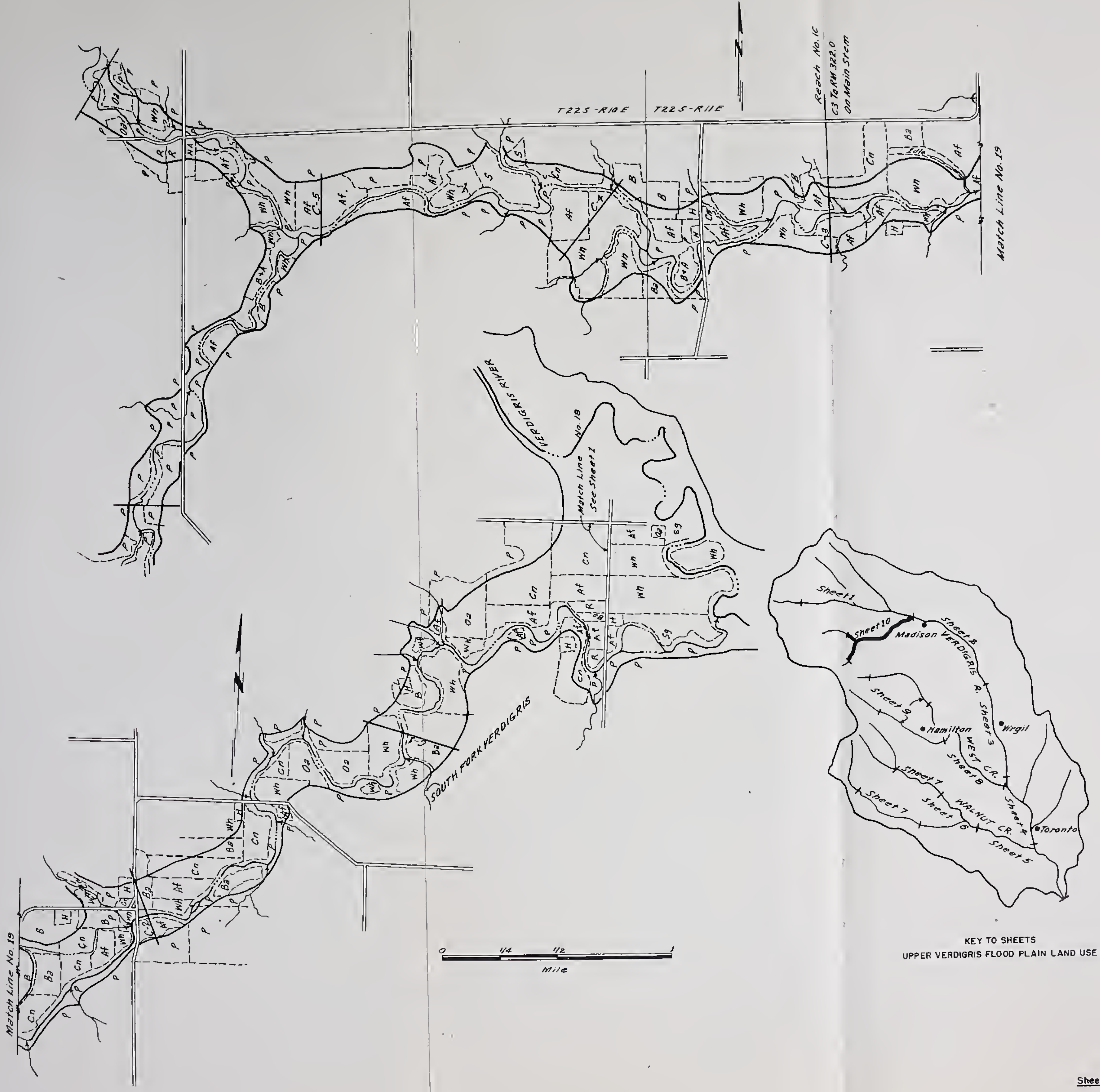

0
1/2
1
Mile
LEGEND
Cn Corn
P Pasture
Oa Oats
Wh Wheat
F Woods
Af Alfalfa
Ba Barley
H Homestead
Bn Beans
B Brome
Sg Sorghum
Gr.Sg. Grain Sorghum
T23S-R12E
T24S-R12E
T23S-R11E
T24S-R11E
Reach No. 2B
B-3-30
B-20
B-21
B-22
Match Line No.17 See Sheet 9
Match Line No.16 See Sheet 9
Match Line No.15
Match Line No.14 See Sheet 4
Reach No. 4B
To R.M. 290.5 on Mainstem
B-A
B-1
T24S-R12E
T24S-R13E
T25S-R12E
T25S-R13E
Sheet 1
Sheet 10
Sheet 2
Sheet 3
Sheet 9
Sheet 8
Sheet 7
Sheet 6
Sheet 5
Sheet 4
Madison
VERDIGRIS R.
WEST CR.
WALNUT CR.
Hamilton
Virgil
Toronto
KEY TO SHEETS
UPPER VERDIGRIS FLOOD PLAIN LAND USE

Sheet 8 of 10

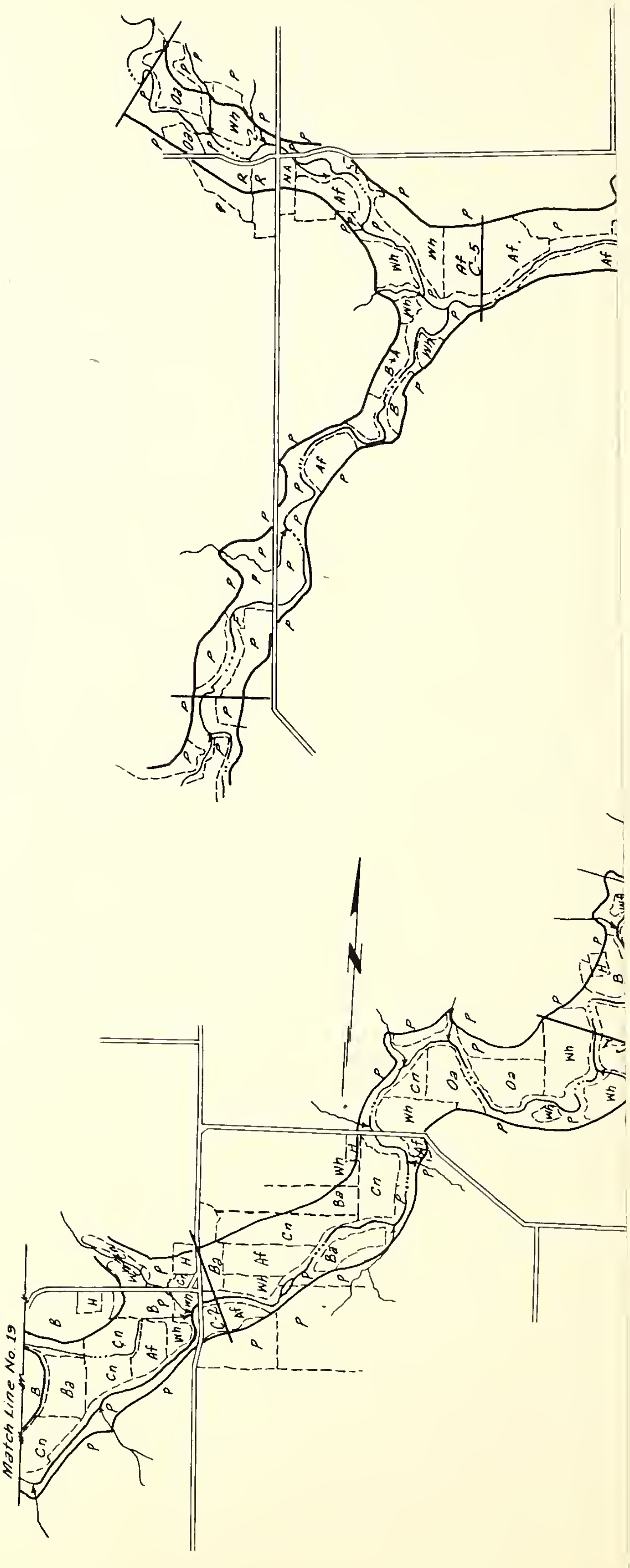

KEY TO SHEETS
UPPER VERDIGRIS FLODD PLAIN LAND USE
Sheet 1
Sheet 2
Sheet 3
Sheet 4
Sheet 5
Sheet 6
Sheet 7
Sheet 8
Sheet 9
Sheet 10
Madison
VERDIGRIS R.
WEST CR.
WALNUT CR.
Hamilton
Virgil
Toronto
LEGEND
Cn Corn
P Pasture
Oa Oats
Wh Wheat
F Woods
Af Alfalfa
Ba Barley
H Homestead
Sg Sorghum
Bn Beans
B Brome
BP Brome Pasture
0 1/4 1/2 1
Mile
NOTE: B-3 & B-4 Sample Areas On Which Damage Schedules Was Made
Reach No. 1B
B3-24
Reach No. 3B
B3-9
Match Line 17 See Sheet
Match Line No. 16 See Sheet 8
T23S-R11E
T24S-R11E
T24S-R12E
Hamilton
B-24
B-23
B-22
B-9
B-8
B-10
B-11
Brome

Sheet 9 of 10

LEGEND	
Cn	Corn
P	Pasture
Oa	Oats
Wh	Wheat
Af	Alfalfa
Ba	Barley
H	Homestead
B	Brome
R	Rye
BA	Brome + Alfalfa
BP	Brome Pasture
S	Sudan
Sg	Sorghum



KEY TO SHEETS
UPPER VERDIGRIS FLOOD PLAIN LAND USE



LEGEND

Cn	Corn
P	Pasture
Oa	Oats
Wh	Wheat
Af	Alfalfa
Ba	Barley
H	Homestead
B	Brome
R	Rye
BA	Brome + Alfalfa
BP	Brome Pasture
S	Sudan
Sg	Sorghum

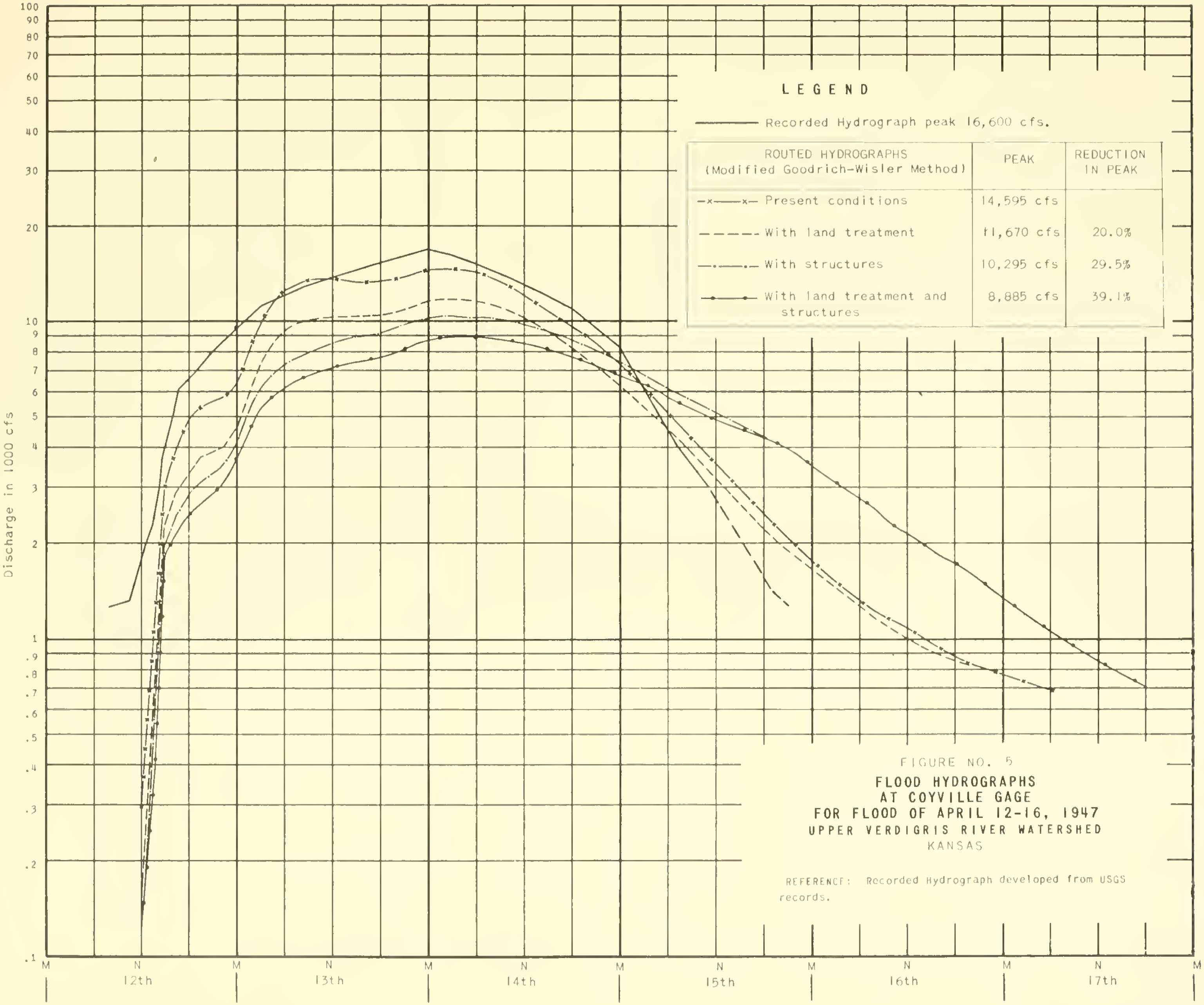


FIGURE NO. 5

FLOOD HYDROGRAPHS
AT COYVILLE GAGE
FOR FLOOD OF APRIL 12-16, 1947
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: Recorded Hydrograph developed from USGS records.

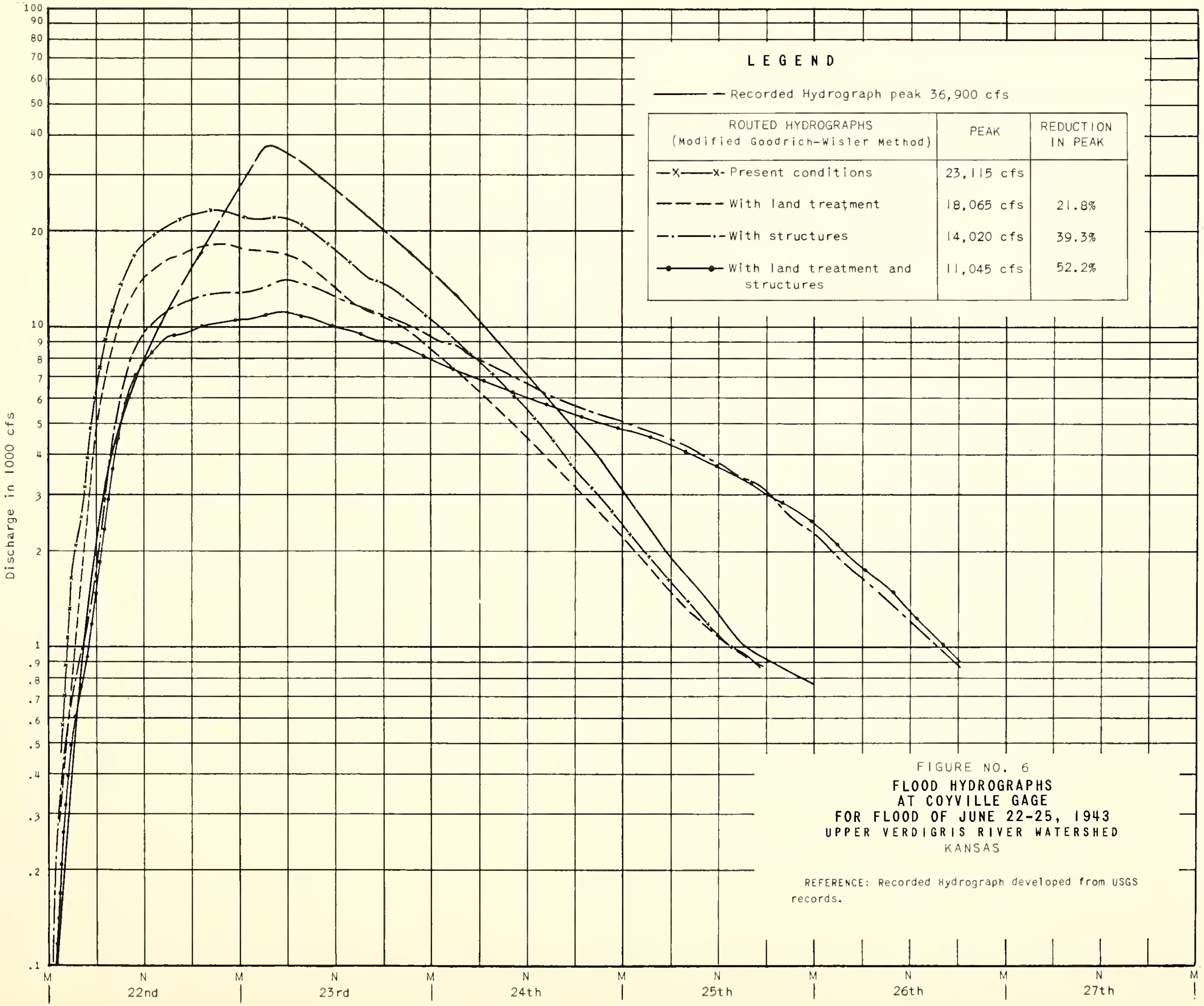


FIGURE NO. 6

FLOOD HYDROGRAPHS
AT COYVILLE GAGE
FOR FLOOD OF JUNE 22-25, 1943
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: Recorded Hydrograph developed from USGS records.

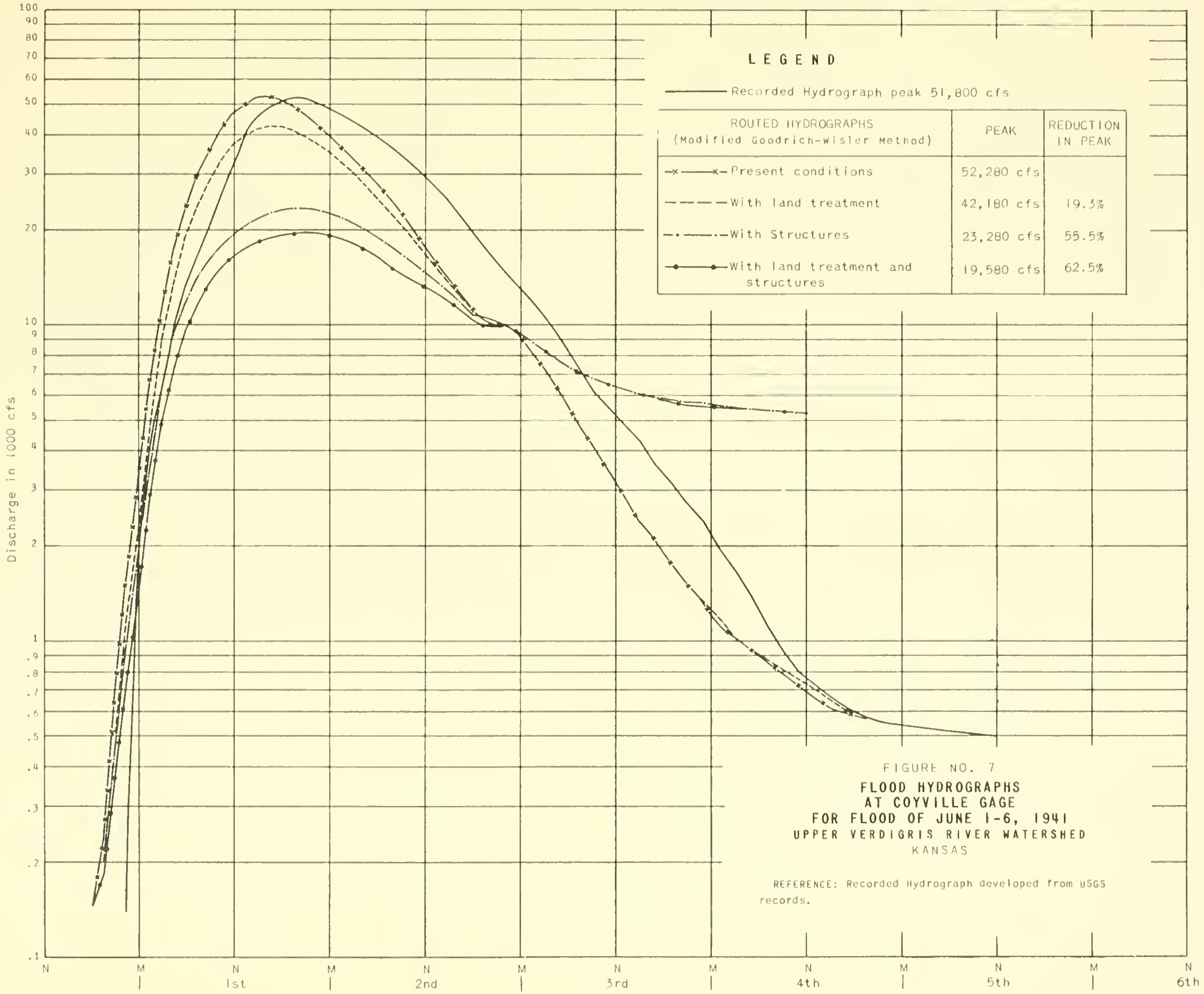


FIGURE NO. 7

FLOOD HYDROGRAPHS
AT COYVILLE GAGE
FOR FLOOD OF JUNE 1-6, 1941
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: Recorded Hydrograph developed from USGS records.

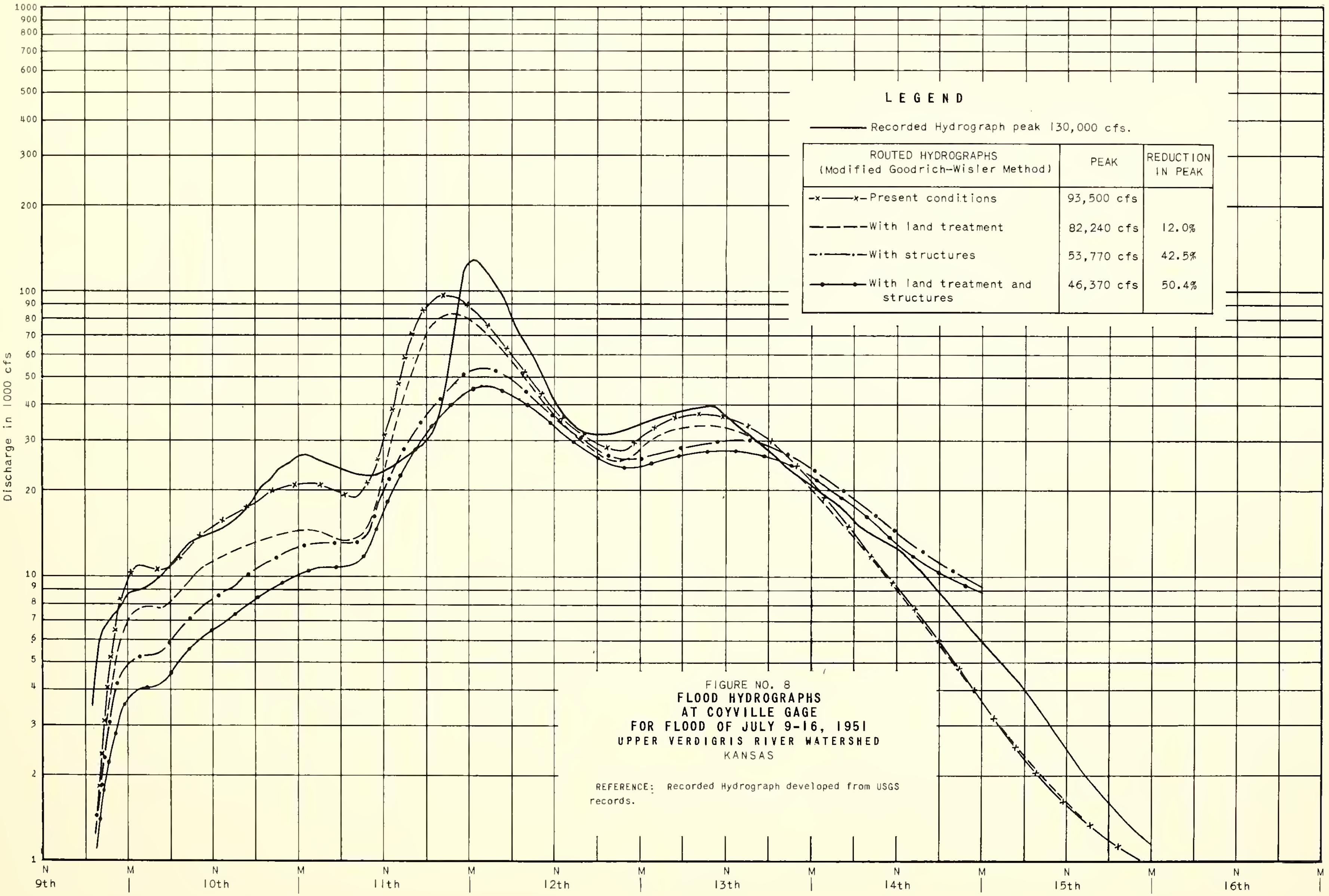


FIGURE NO. 8
FLOOD HYDROGRAPHS
AT COYVILLE GAGE
FOR FLOOD OF JULY 9-16, 1951
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: Recorded Hydrograph developed from USGS records.

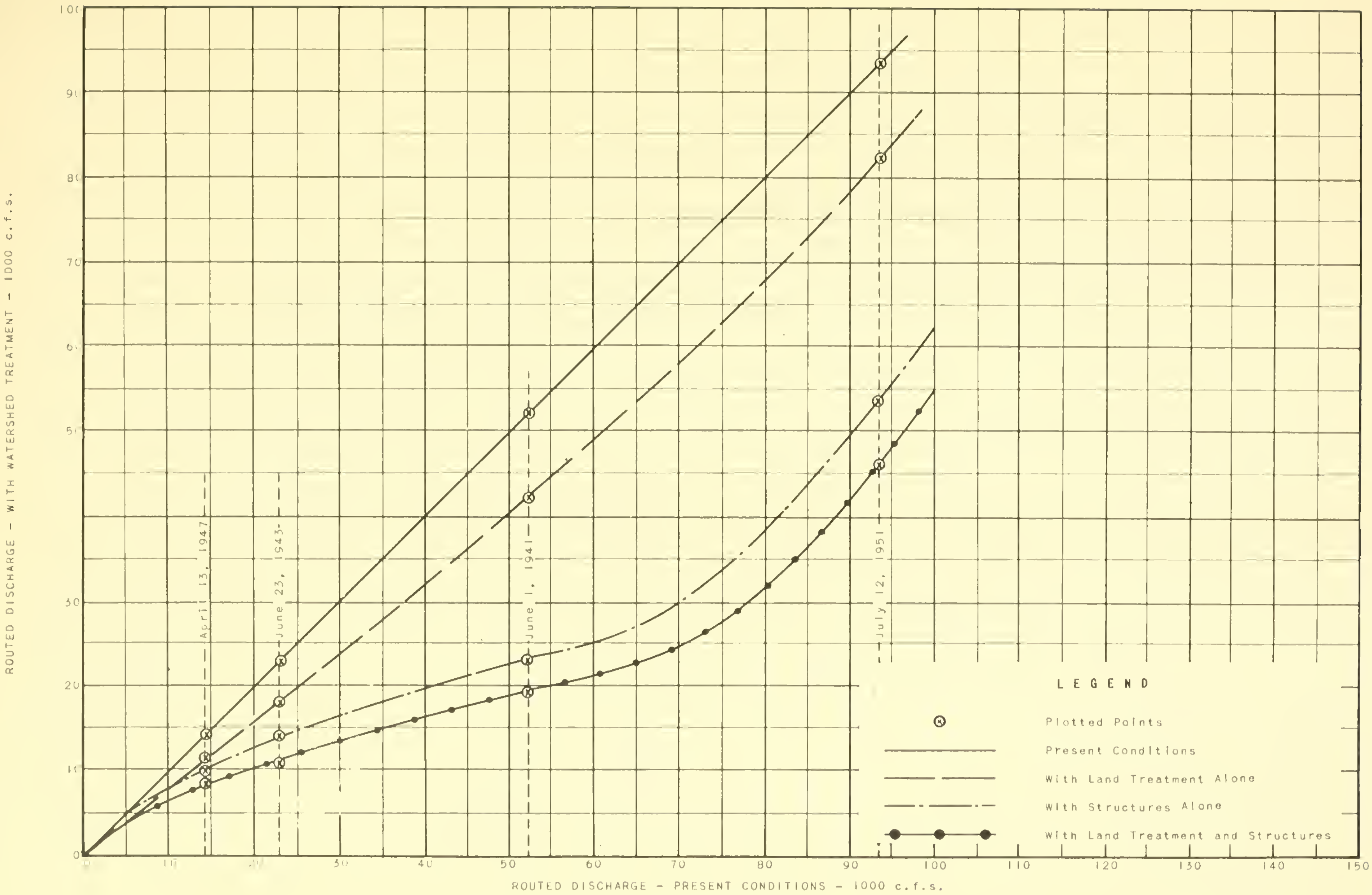


FIGURE NO. 9
EFFECT OF PROGRAM ON PEAK DISCHARGE AT COYVILLE, KANSAS
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

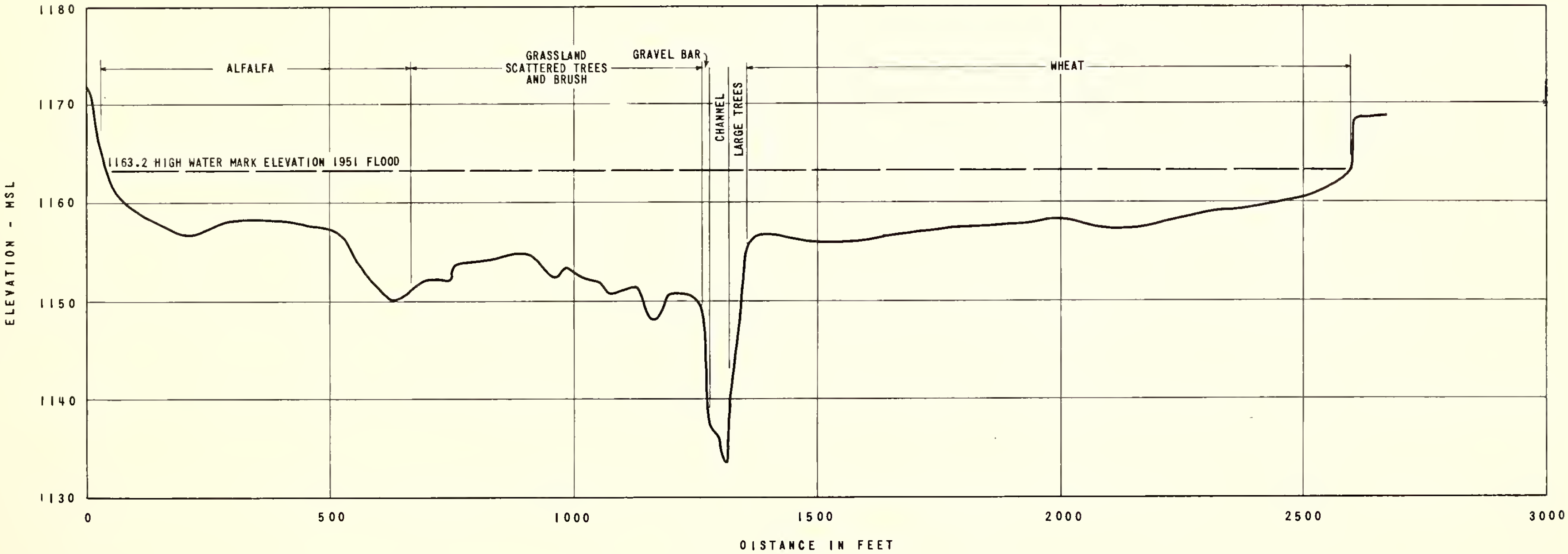


FIGURE NO. 10

VALLEY CROSS SECTION
MAIN STEM RM 339.3

UPPER VERDIGRIS RIVER WATERSHED
KANSAS

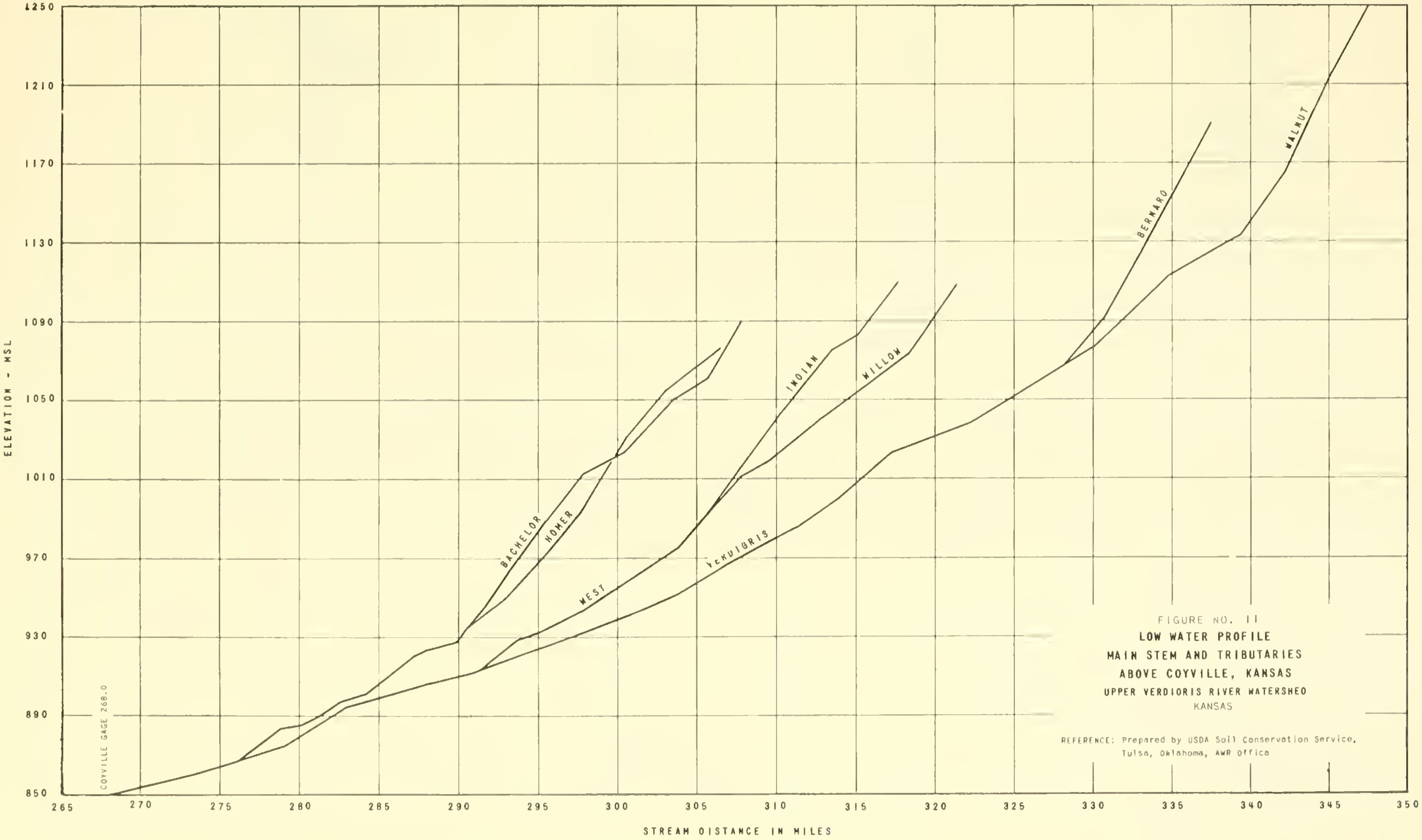


FIGURE NO. 11

LOW WATER PROFILE
MAIN STEM AND TRIBUTARIES
ABOVE COYVILLE, KANSAS
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: Prepared by USDA Soil Conservation Service,
Tulsa, Oklahoma, AWR Office

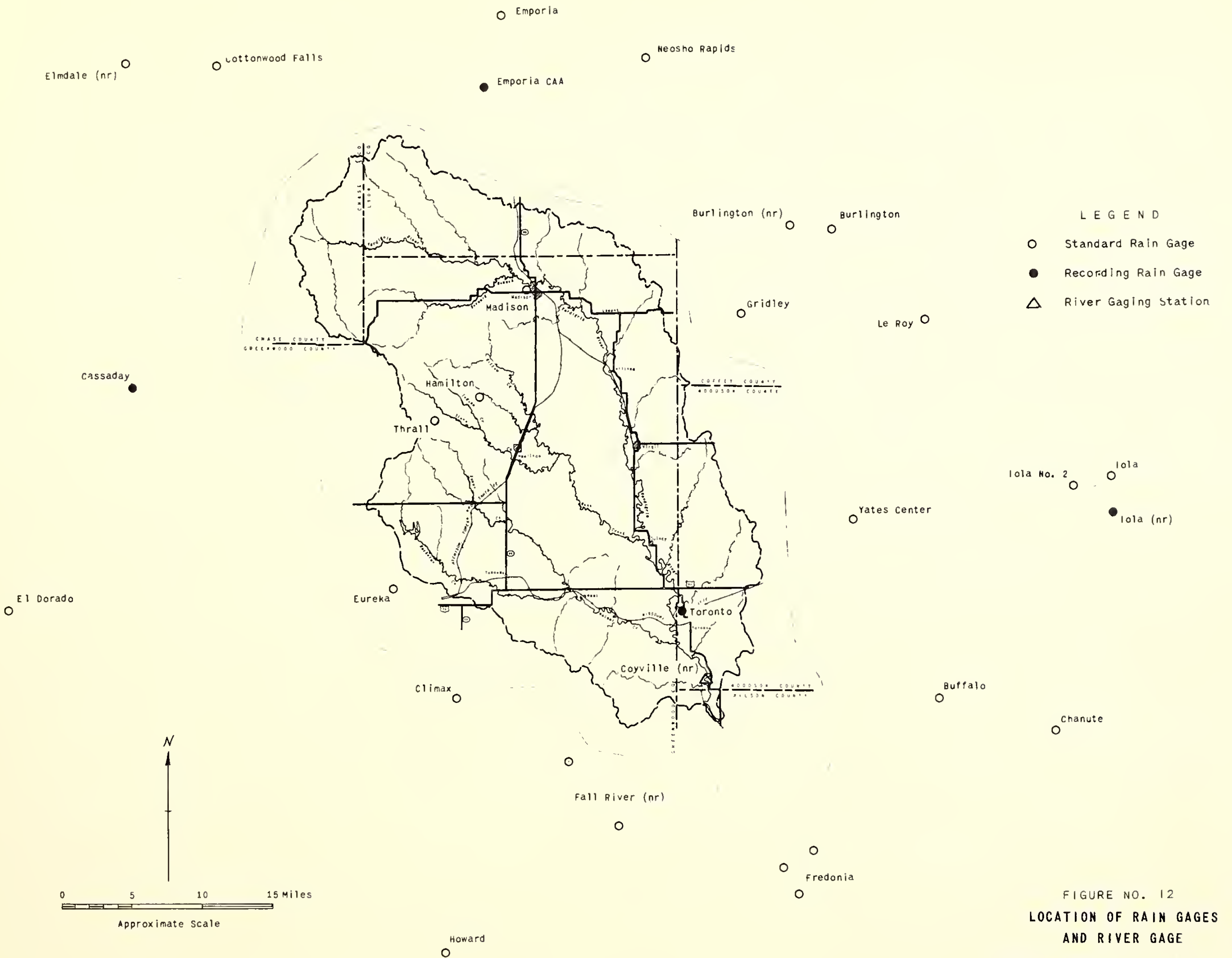


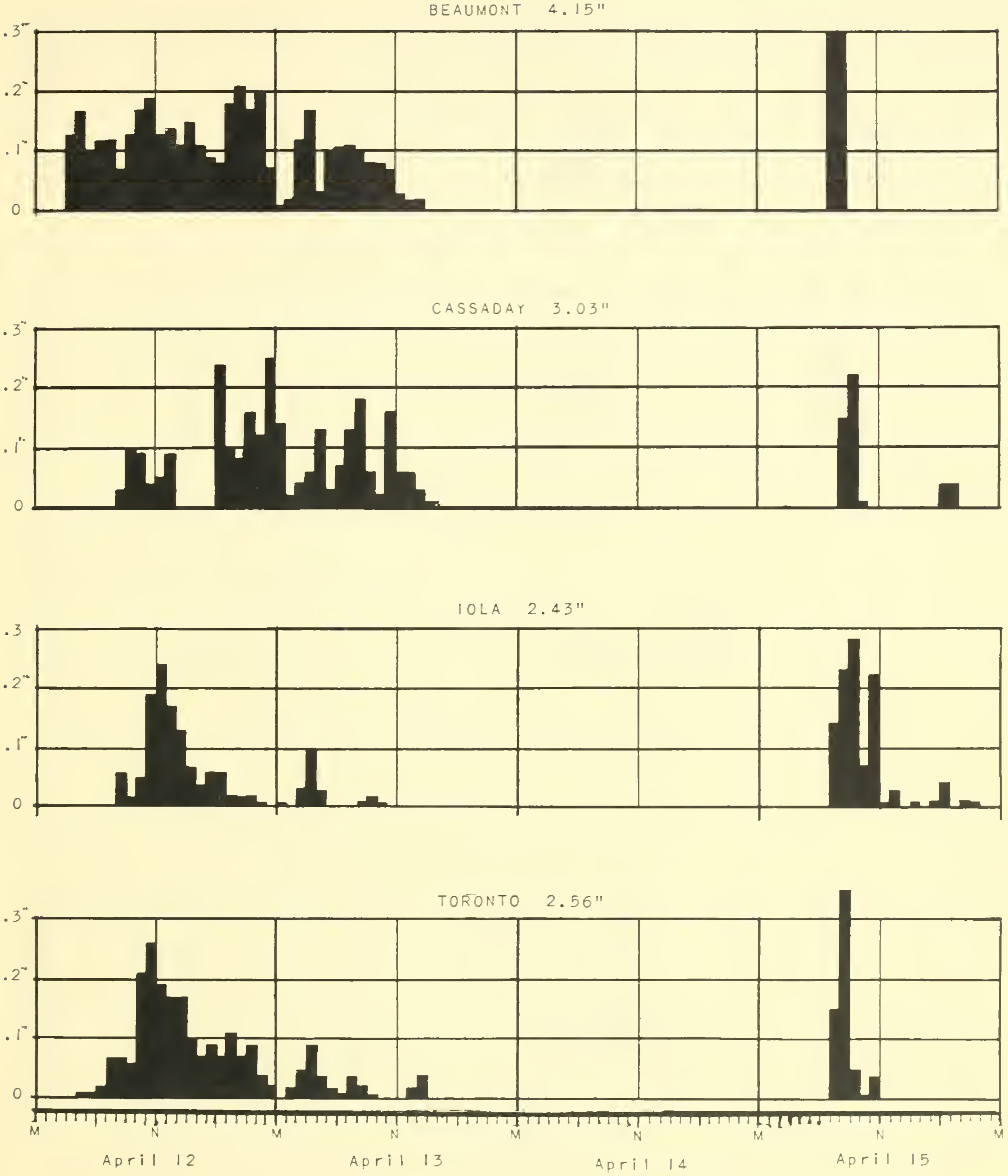
FIGURE NO. 12

LOCATION OF RAIN GAGES
AND RIVER GAGE

UPPER VERDIGRIS RIVER WATERSHED

KANSAS

REFERENCE; River Basin Maps showing Hydrologic Stations by Federal Inter-Agency River Basin Committee.



BEAUMONT 4.15"

CASSADAY 3.03"

IOLA 2.43"

TORONTO 2.56"

FIGURE NO. 13

RAINFALL AT RECORDING GAGE

APRIL 12-15, 1947

UPPER VERDIGRIS RIVER WATERSHED

KANSAS

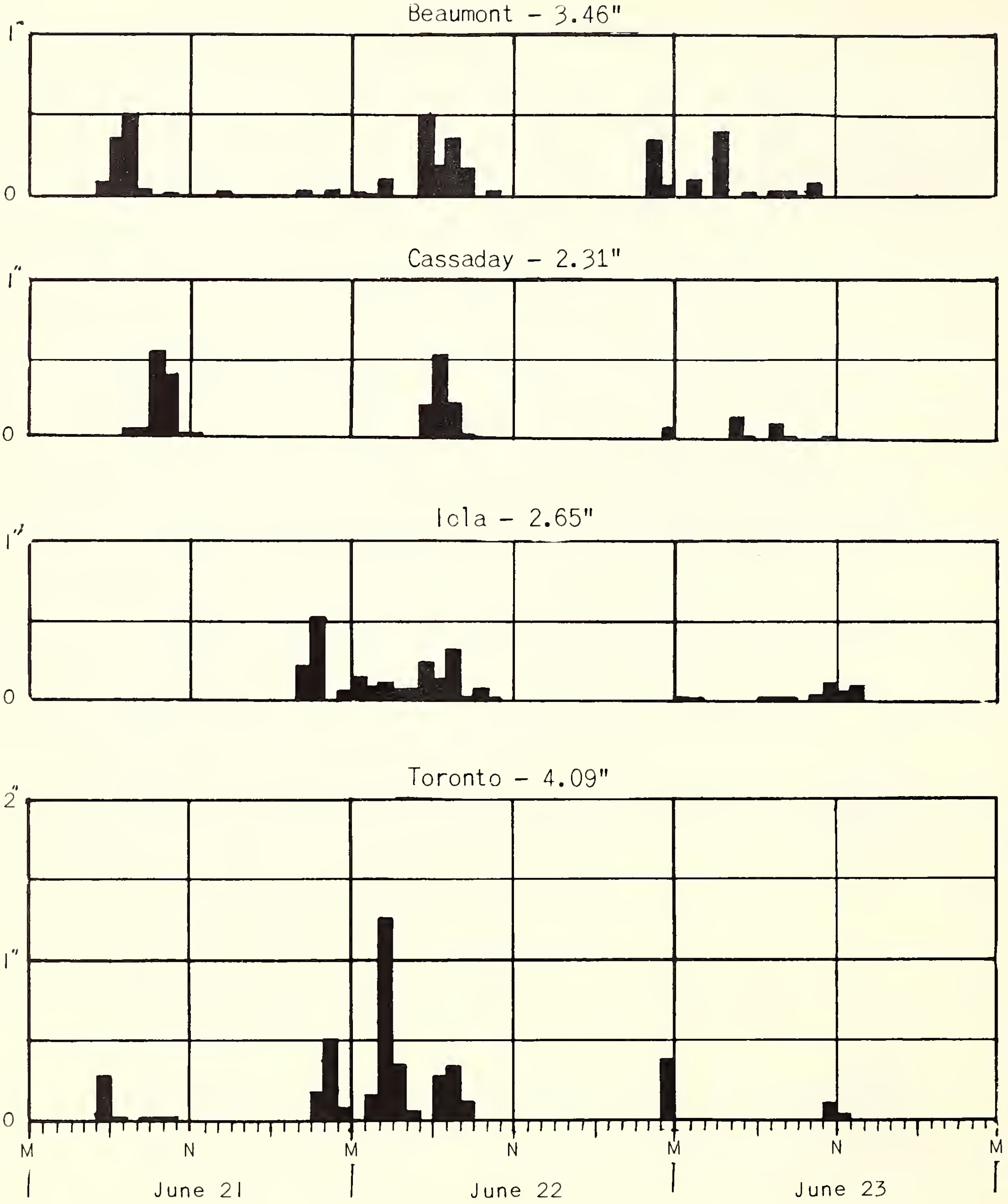
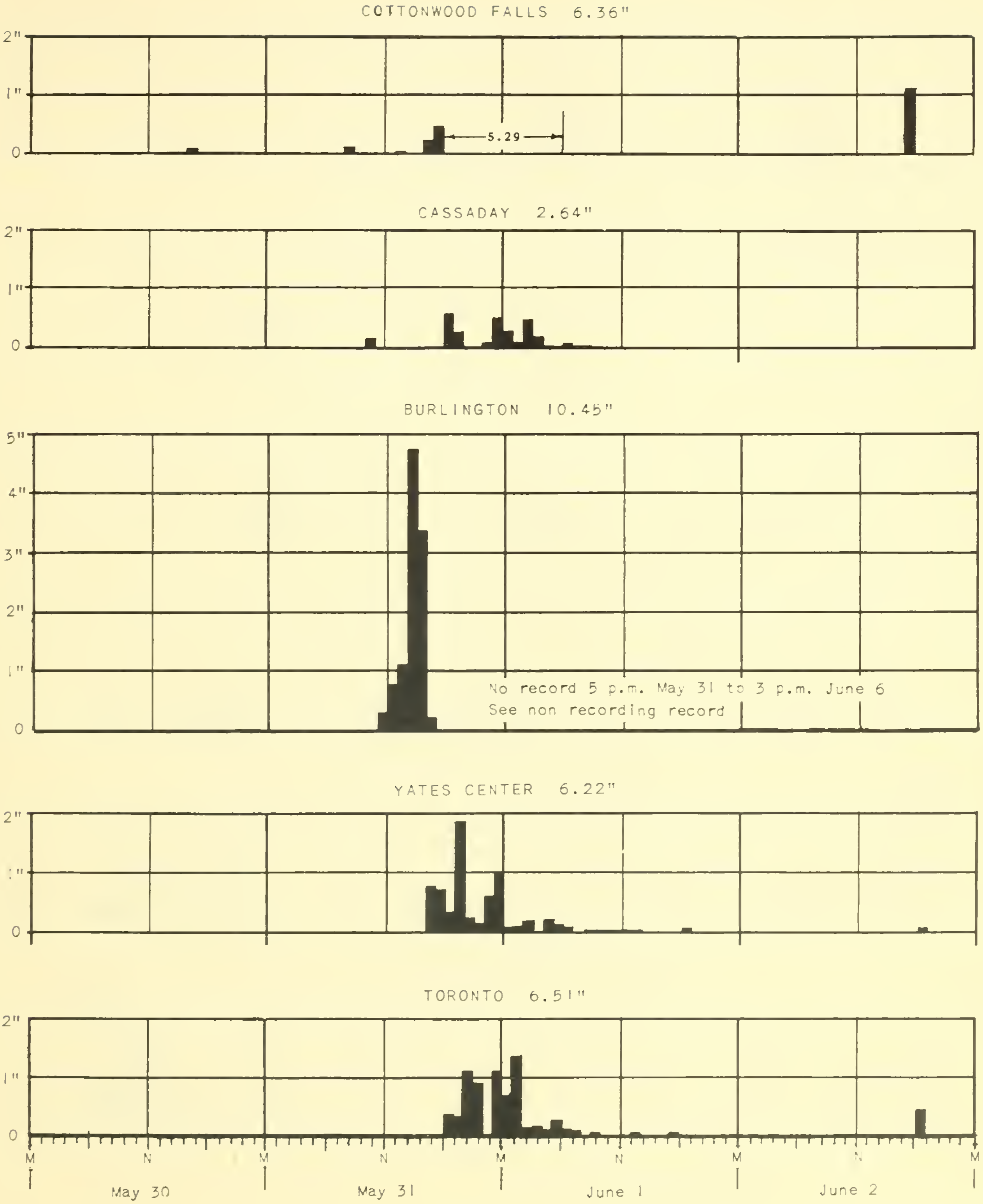


FIGURE NO. 14

RAINFALL AT RECORDING GAGES
JUNE 21-23, 1943

UPPER VERDIGRIS RIVER WATERSHED
KANSAS



COTTONWOOD FALLS 6.36"

CASSADAY 2.64"

BURLINGTON 10.45"

No record 5 p.m. May 31 to 3 p.m. June 6
See non recording record

YATES CENTER 6.22"

TORONTO 6.51"

FIGURE NO. 15

RAINFALL AT RECORDING GAGES

MAY 30, JUNE 2, 1941

UPPER VERDIGRIS RIVER WATERSHED
KANSAS

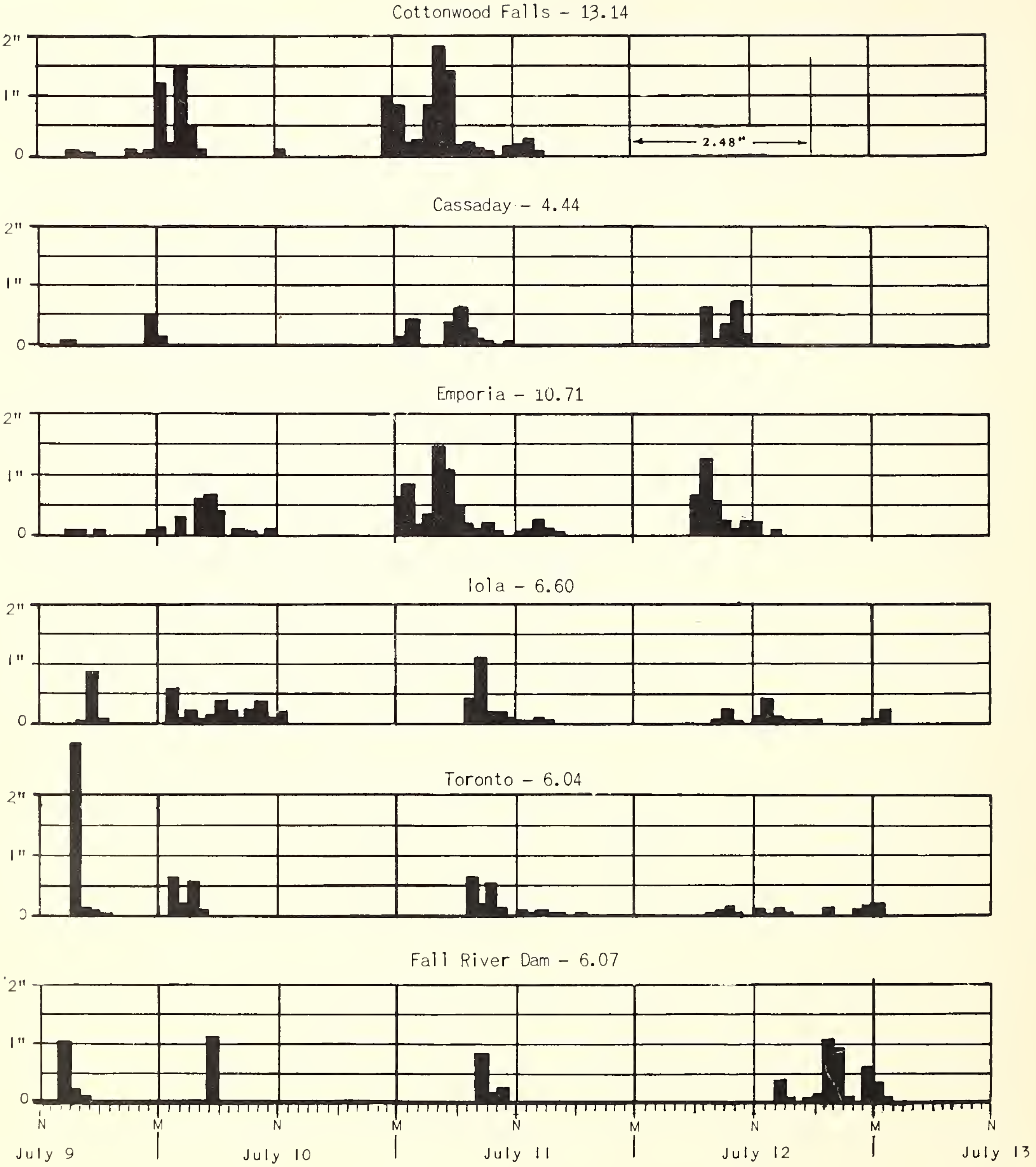


FIGURE NO. 16
RAINFALL AT RECORDING GAGES
JULY 9-13, 1951
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

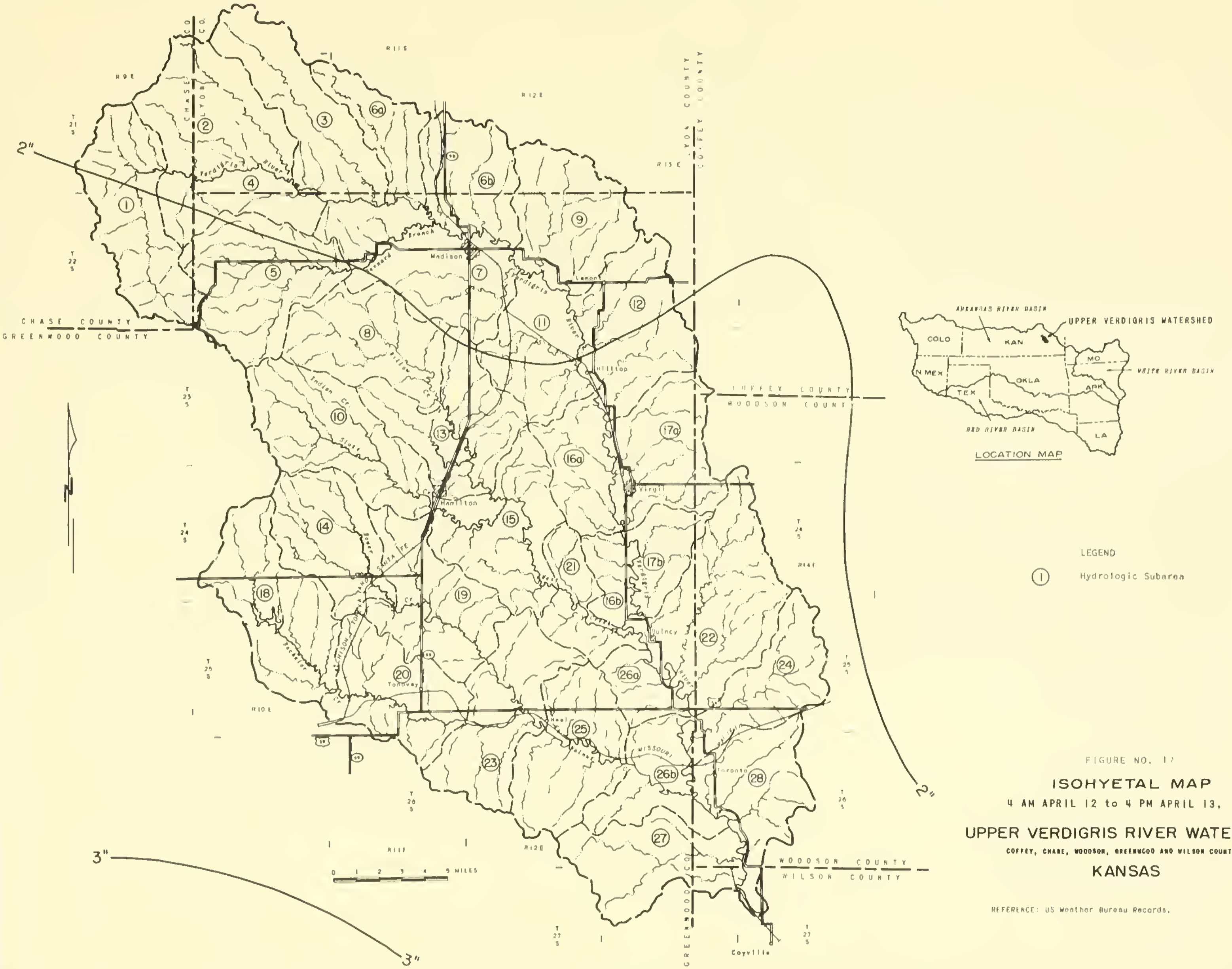


FIGURE NO. 17

ISOHYETAL MAP

4 AM APRIL 12 to 4 PM APRIL 13, 1947

UPPER VERDIGRIS RIVER WATERSHED

COFFEY, CHASE, WOODSON, GREENWOOD AND WILSON COUNTIES

KANSAS

REFERENCE: US Weather Bureau Records.

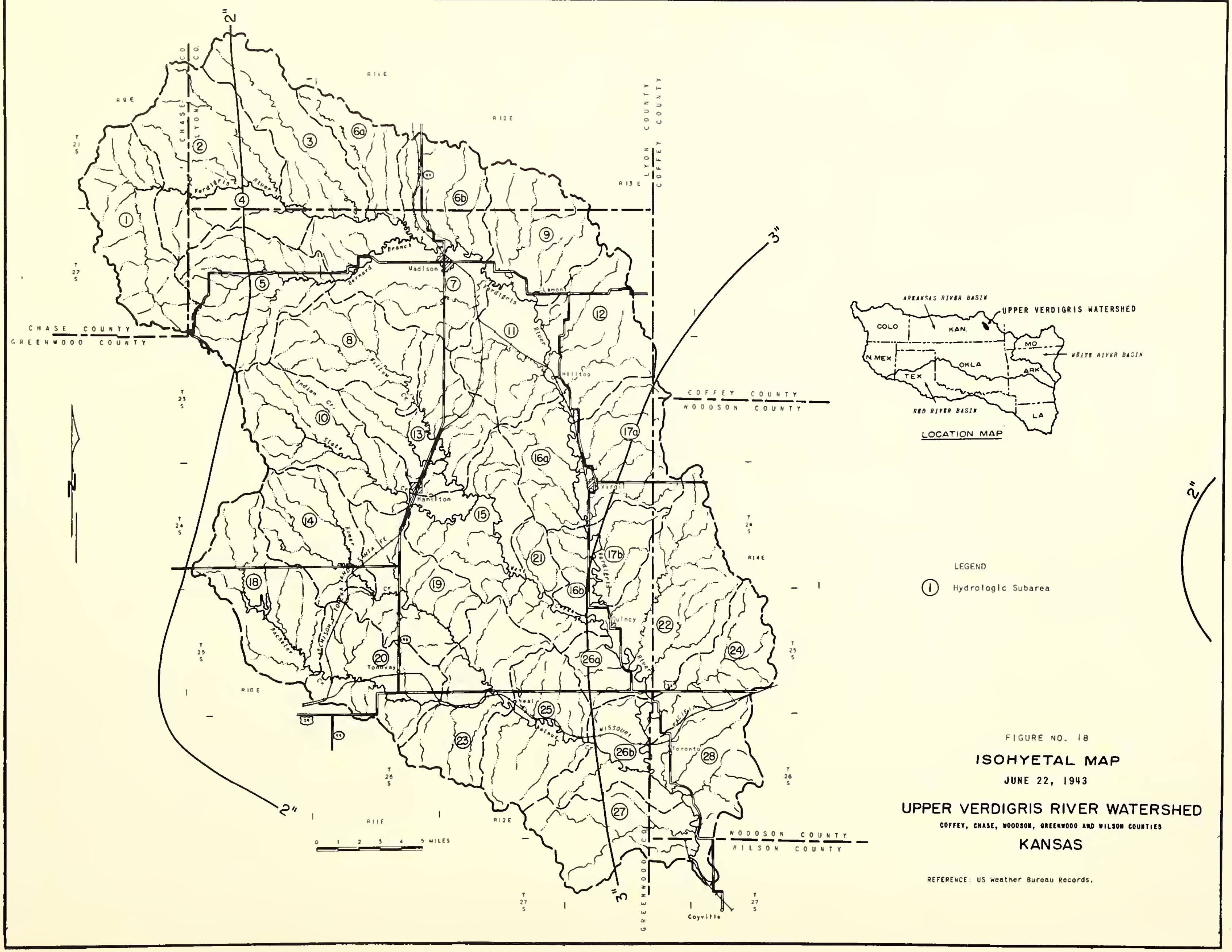


FIGURE NO. 18

ISOHYETAL MAP

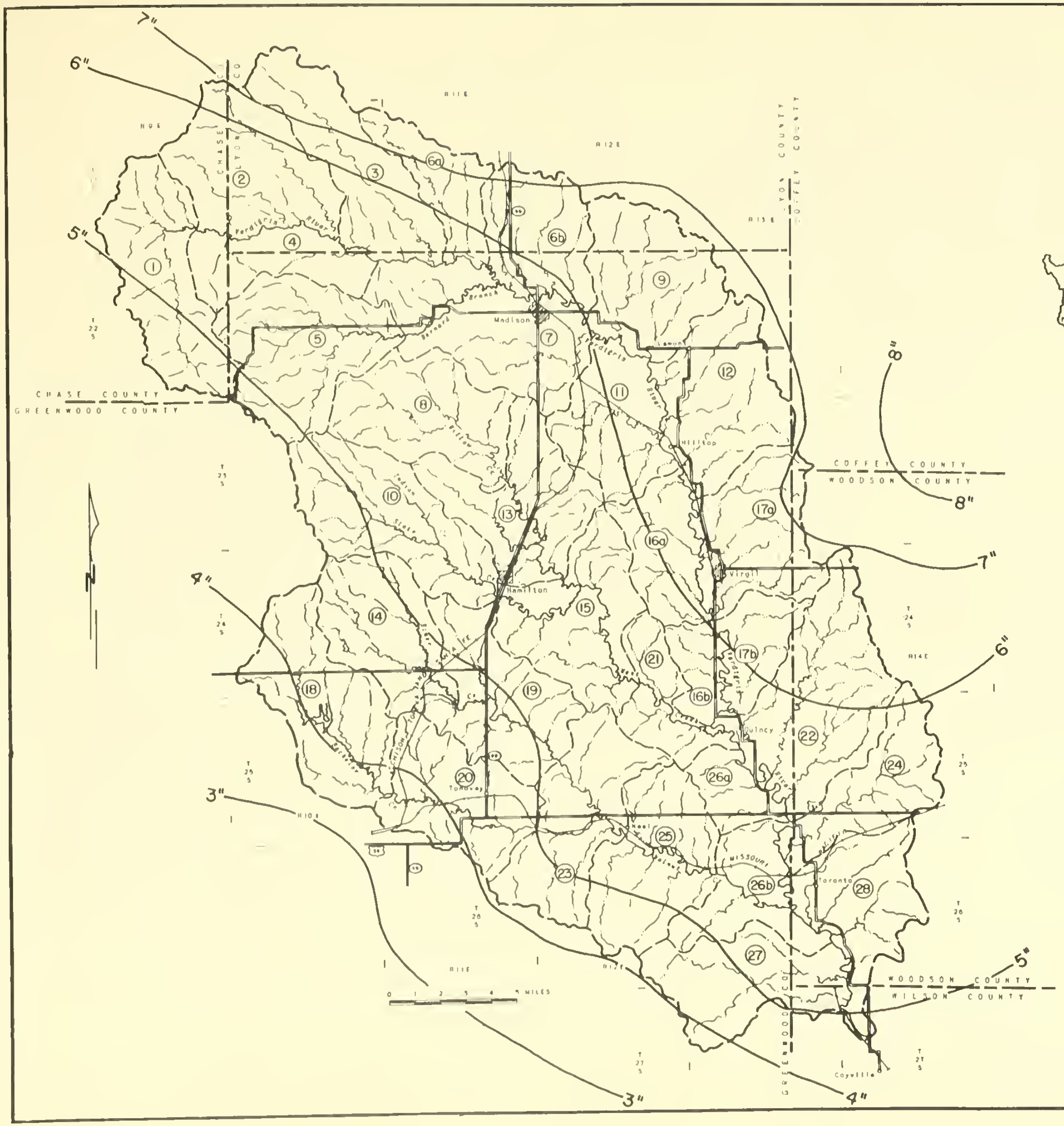
JUNE 22, 1943

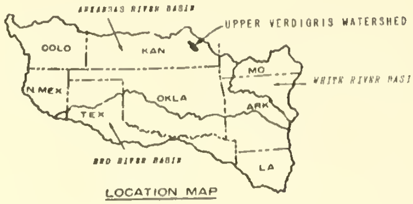
UPPER VERDIGRIS RIVER WATERSHED

COFFEY, CHASE, WOODSON, GREENWOOD AND WILSON COUNTIES

KANSAS

REFERENCE: US Weather Bureau Records.





LOCATION MAP

LEGEND

① Hydrologic Subarea

FIGURE NO. 19

ISOHYETAL MAP

24 HOUR PRECIPITATION FROM NOON
MAY 31 to NOON JUNE 1, 1941

UPPER VERDIGRIS RIVER WATERSHED

COFFEY, CHASE, WOODSON, GREENWOOD AND WILSON COUNTIES

KANSAS

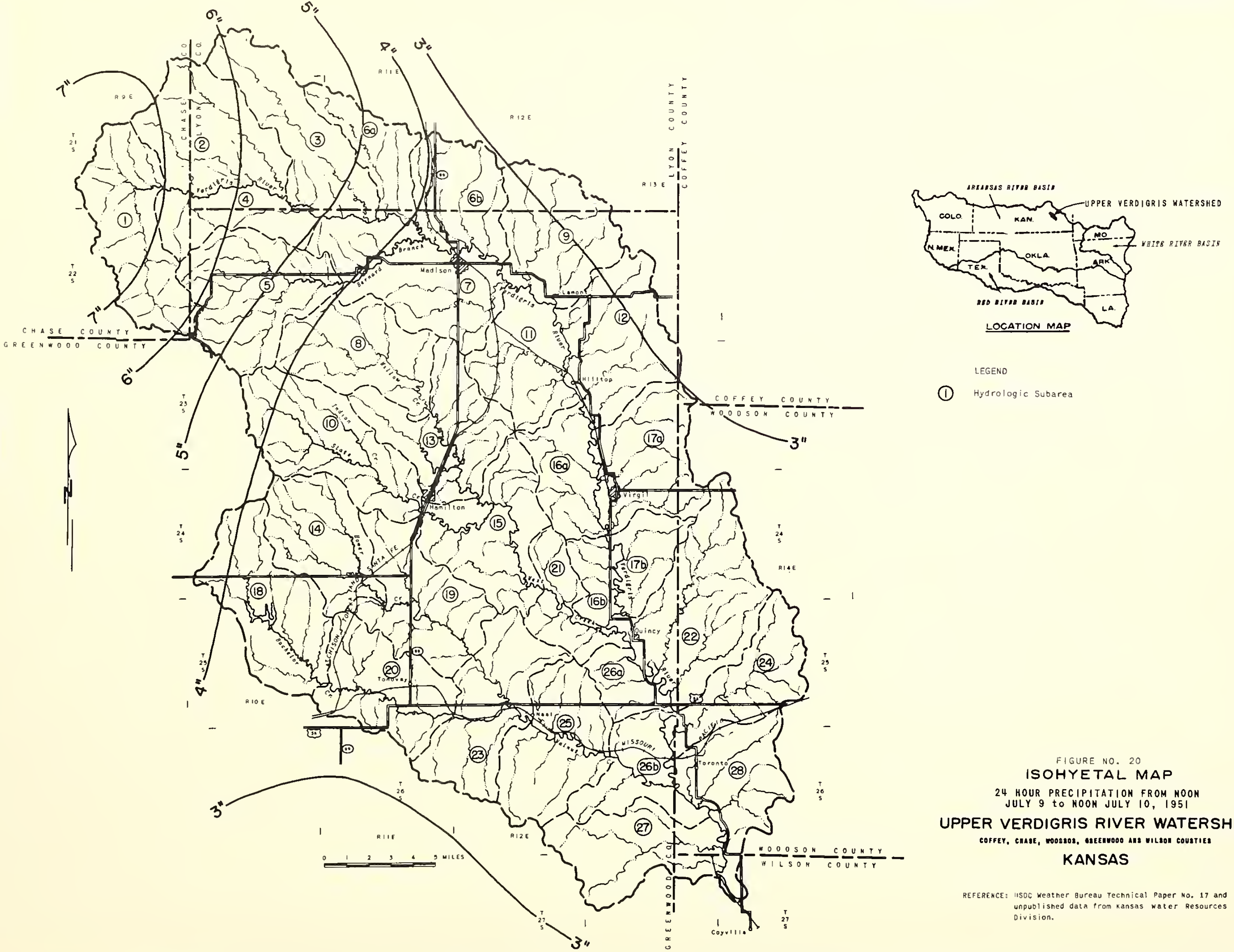


FIGURE NO. 20

ISOHYETAL MAP

24 HOUR PRECIPITATION FROM NOON
JULY 9 to NOON JULY 10, 1951

UPPER VERDIGRIS RIVER WATERSHED

COFFEY, CHASE, WOODSON, GREENWOOD AND WILSON COUNTIES

KANSAS

REFERENCE: USDC Weather Bureau Technical Paper No. 17 and unpublished data from Kansas Water Resources Division.

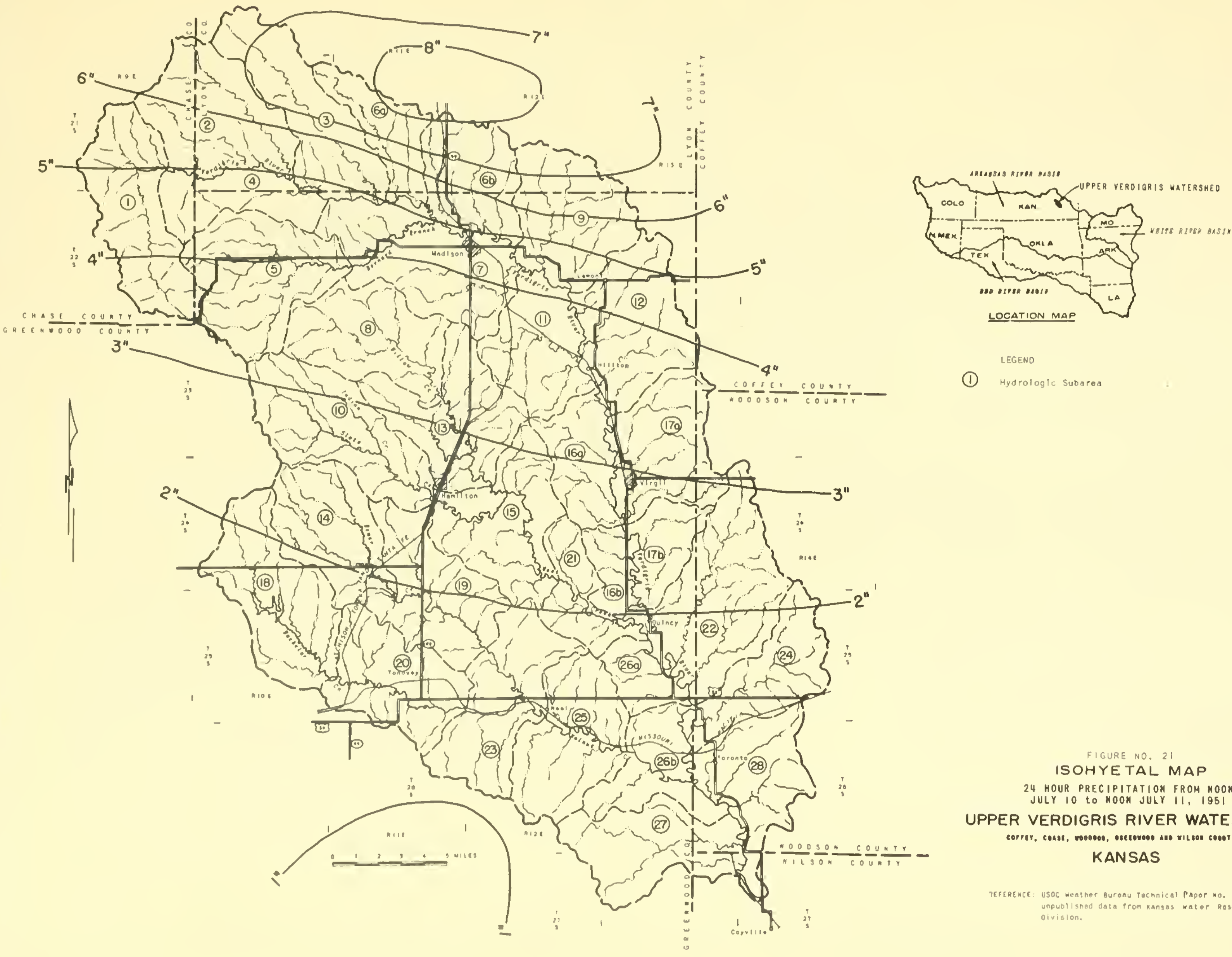


FIGURE NO. 21

ISOHYETAL MAP

24 HOUR PRECIPITATION FROM NOON
JULY 10 to NOON JULY 11, 1951

UPPER VERDIGRIS RIVER WATERSHED

COFFEY, CHASE, WOODSON, GREENWOOD AND WILSON COUNTIES

KANSAS

REFERENCE: USDC Weather Bureau Technical Paper No. 17 and unpublished data from Kansas Water Resources Division.

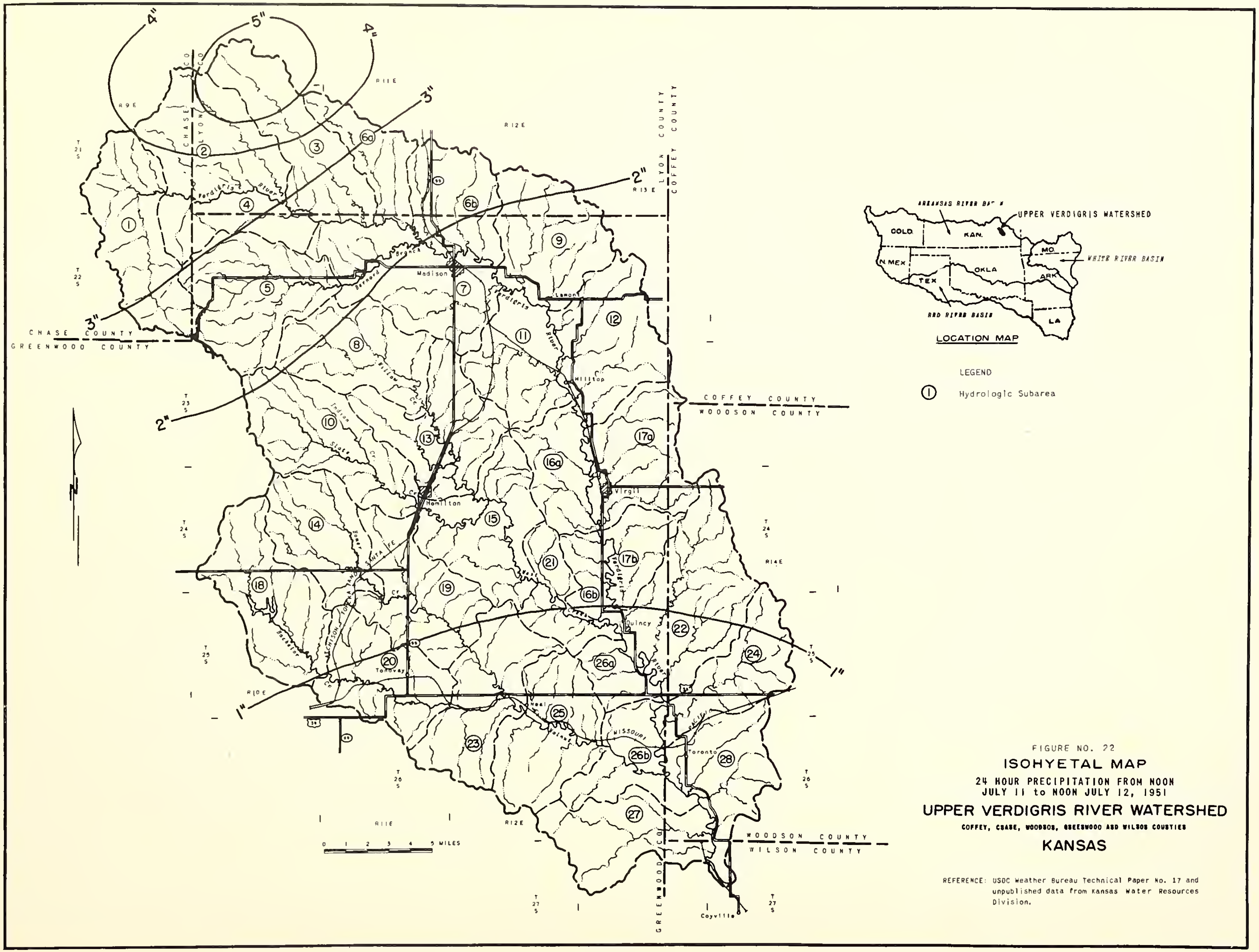


FIGURE NO. 22

ISOHYETAL MAP

24 HOUR PRECIPITATION FROM NOON
JULY 11 to NOON JULY 12, 1951

UPPER VERDIGRIS RIVER WATERSHED

COFFEY, CHASE, WOODSON, GREENWOOD AND WILSON COUNTIES

KANSAS

REFERENCE: USDC Weather Bureau Technical Paper No. 17 and unpublished data from Kansas Water Resources Division.

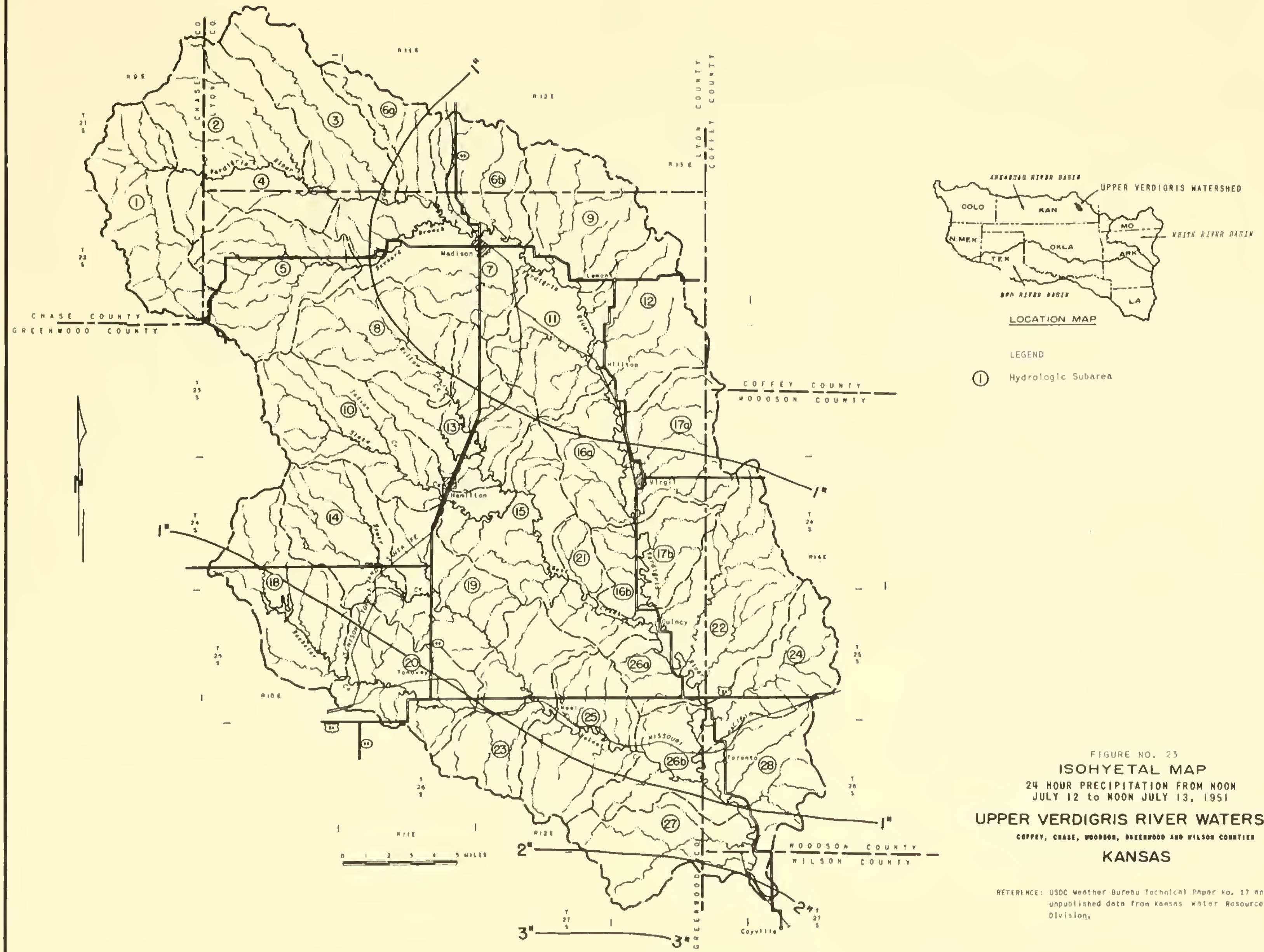


FIGURE NO. 23

ISOHYETAL MAP

24 HOUR PRECIPITATION FROM NOON
JULY 12 to NOON JULY 13, 1951

UPPER VERDIGRIS RIVER WATERSHED

COFFEY, CHASE, WOODSON, GREENWOOD AND WILSON COUNTIES

KANSAS

REFERENCE: USDC Weather Bureau Technical Paper No. 17 and unpublished data from Kansas Water Resources Division.

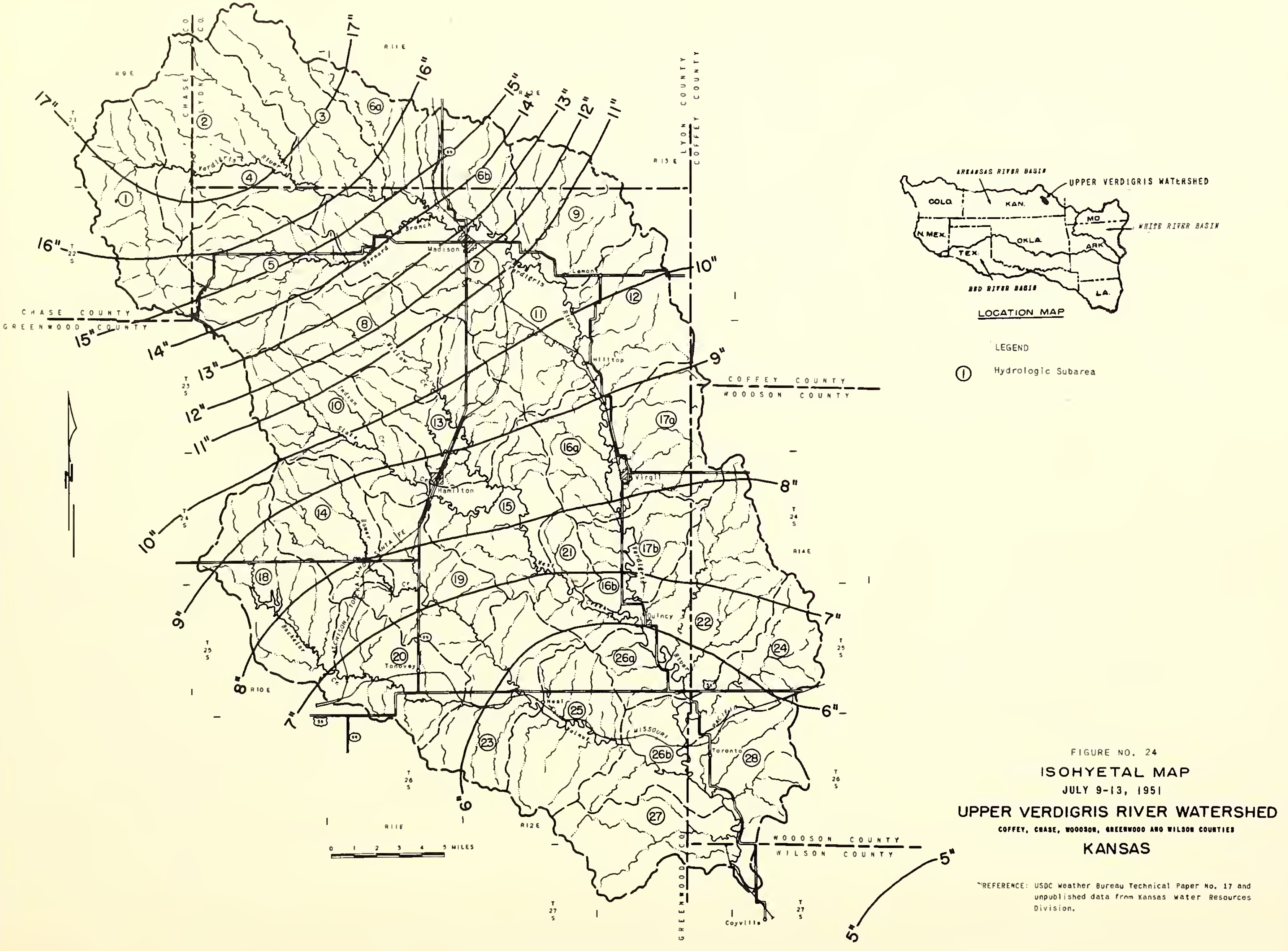


FIGURE NO. 24

ISOHYETAL MAP

JULY 9-13, 1951

UPPER VERDIGRIS RIVER WATERSHED

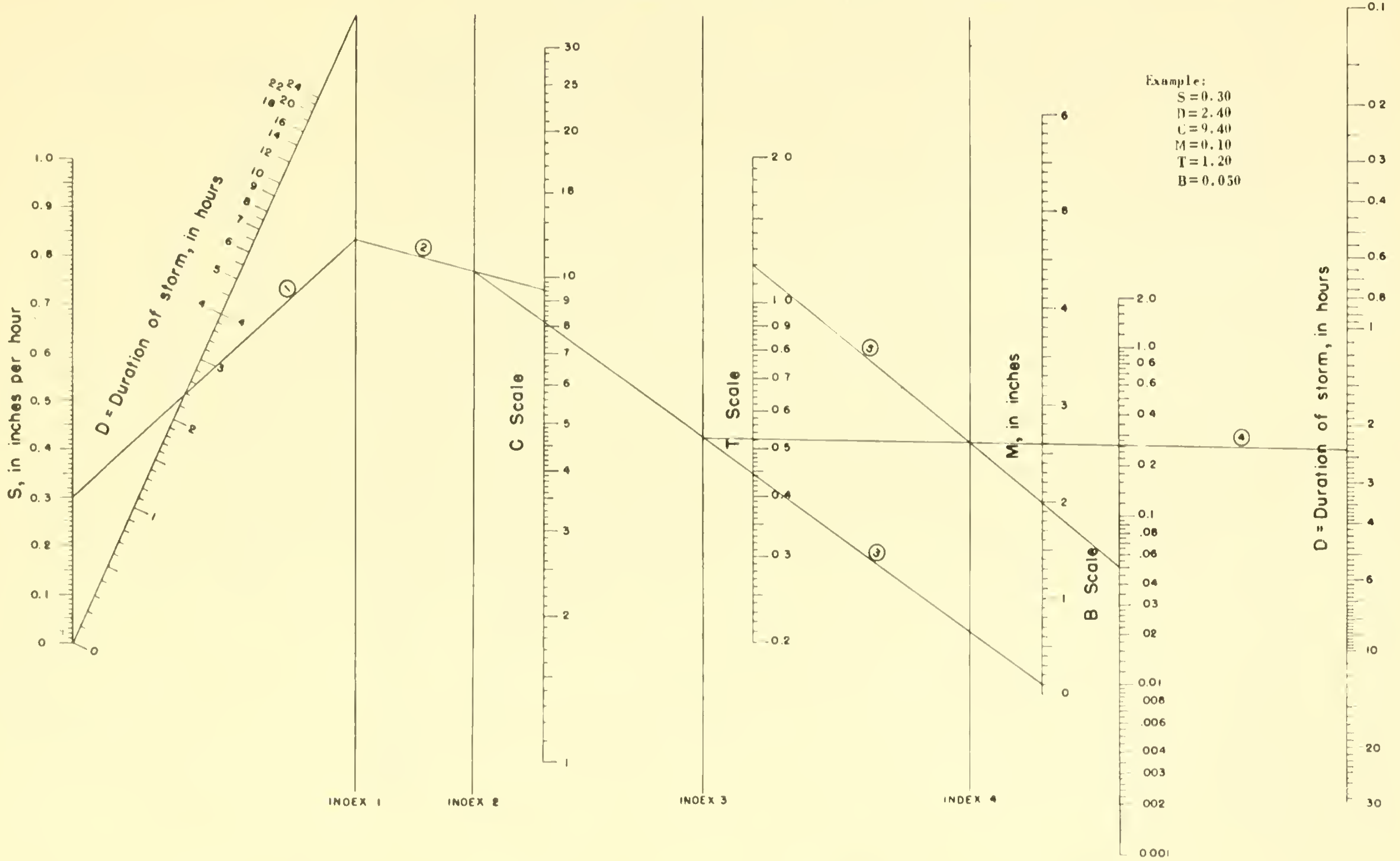
COFFEY, CHASE, WOODSON, GREENWOOD AND WILSON COUNTIES

KANSAS

*REFERENCE: USDC Weather Bureau Technical Paper No. 17 and unpublished data from Kansas Water Resources Division.

Figure 25

Chart for the determination of the Slope Constant in the Runoff Equation



Example:
S = 0.30
D = 2.40
C = 9.40
M = 0.10
T = 1.20
B = 0.050

Lincoln, Nebraska

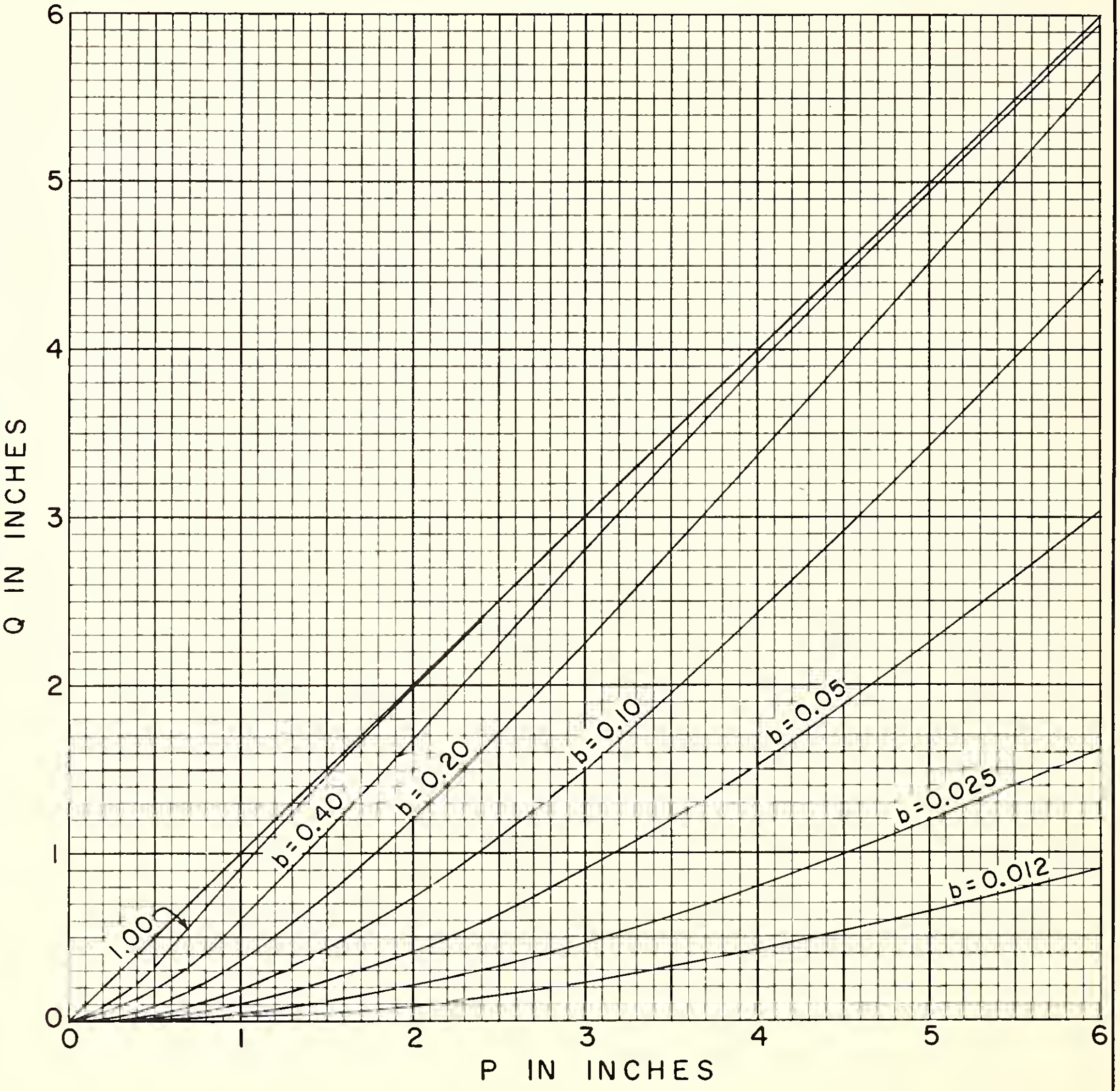
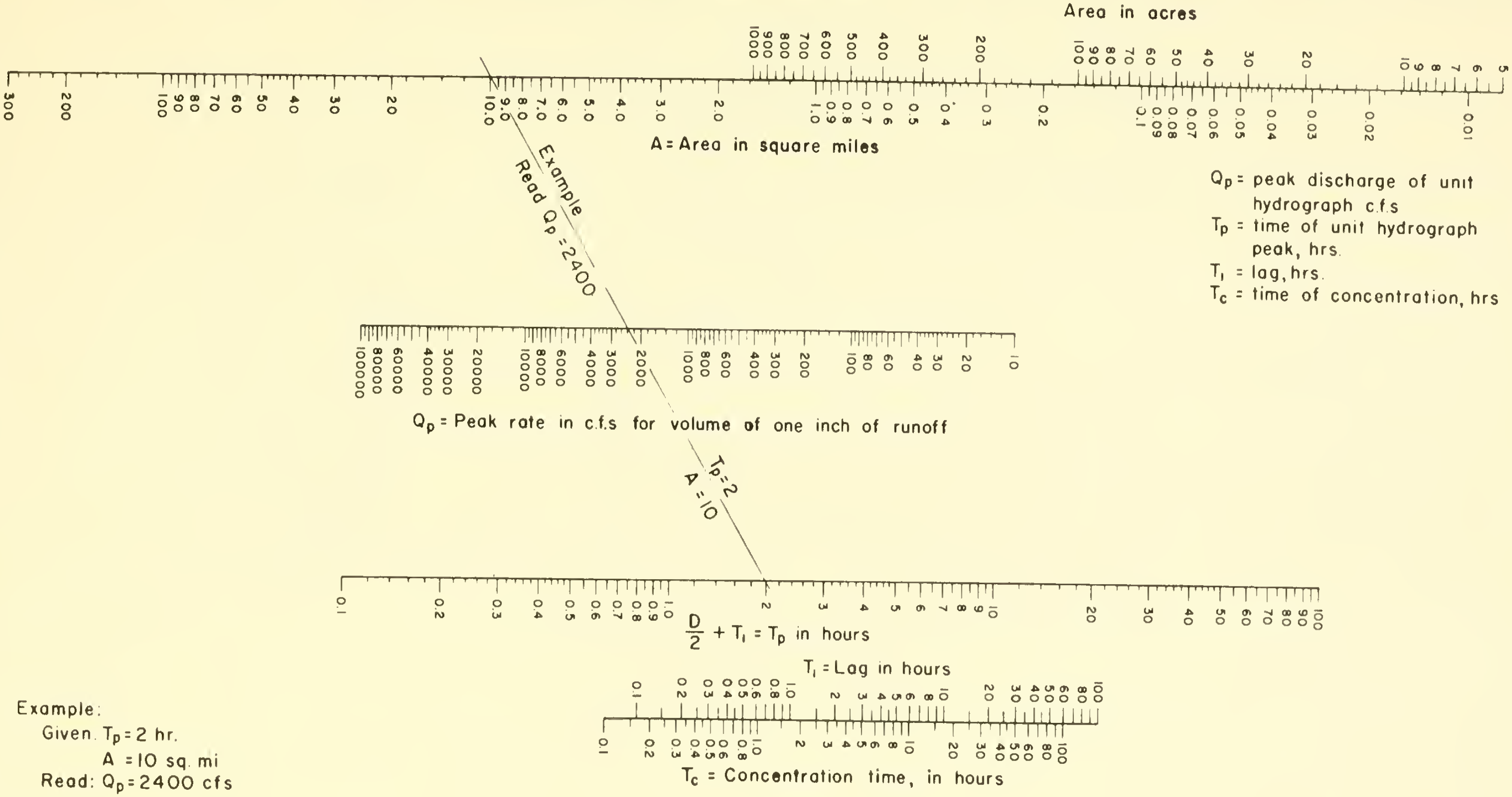


CHART FOR DETERMINING Q

FIGURE 26

HYDROLOGY: DETERMINATION OF PEAK DISCHARGE FOR SYNTHETIC UNIT HYDROGRAPH



Q_p = peak discharge of unit hydrograph c.f.s
T_p = time of unit hydrograph peak, hrs.
T_l = lag, hrs.
T_c = time of concentration, hrs

Example:
Given. $T_p = 2$ hr.
$A = 10$ sq. mi
Read: $Q_p = 2400$ cfs

REFERENCE
Alignment chart developed
by Victor Mockus.

FIGURE 27

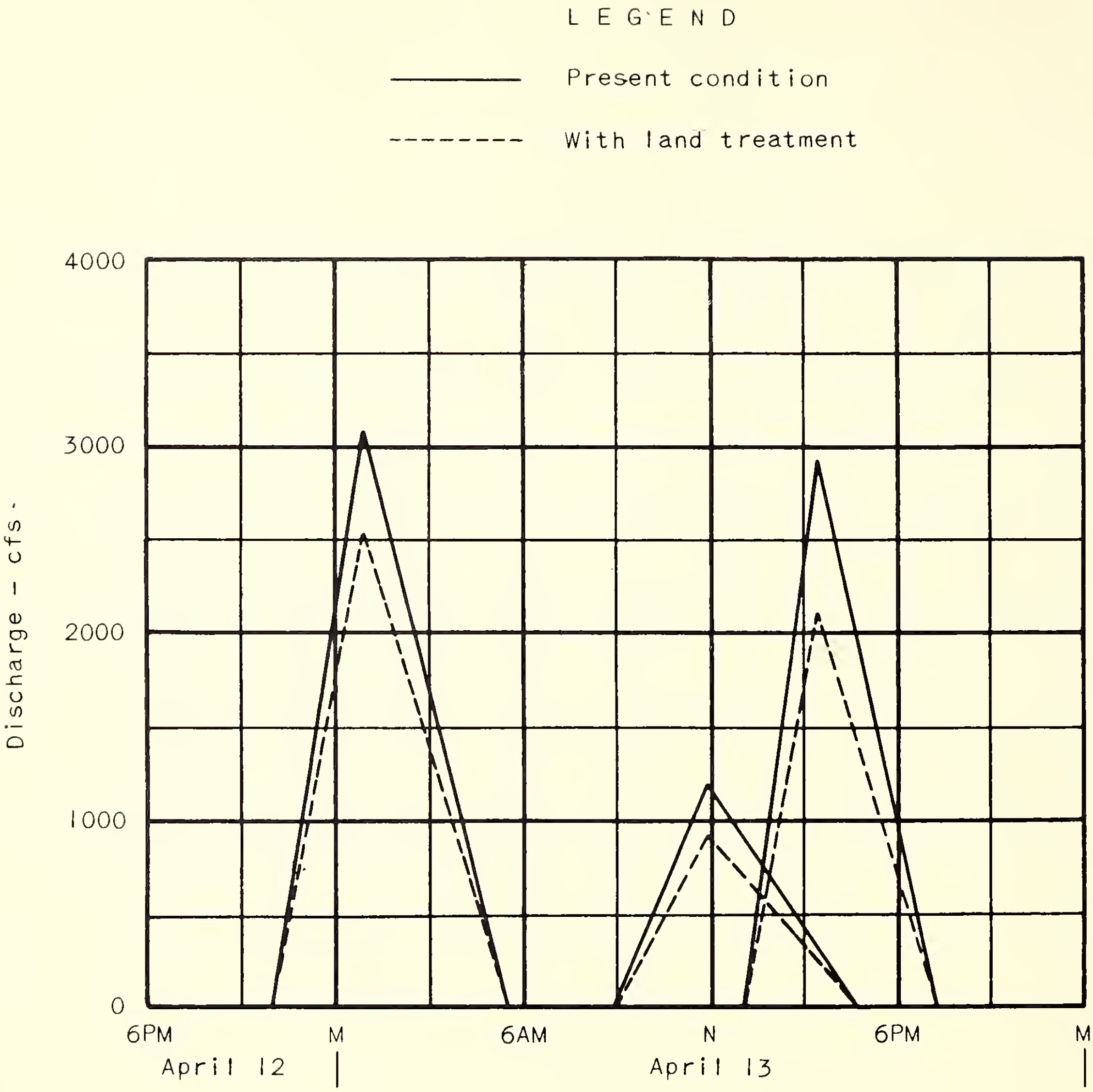


FIGURE NO. 28

COMPUTED HYDROGRAPHS
STORM OF APRIL 12-13, 1947
SUBAREA NO. 5 AT SECTION C-3
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

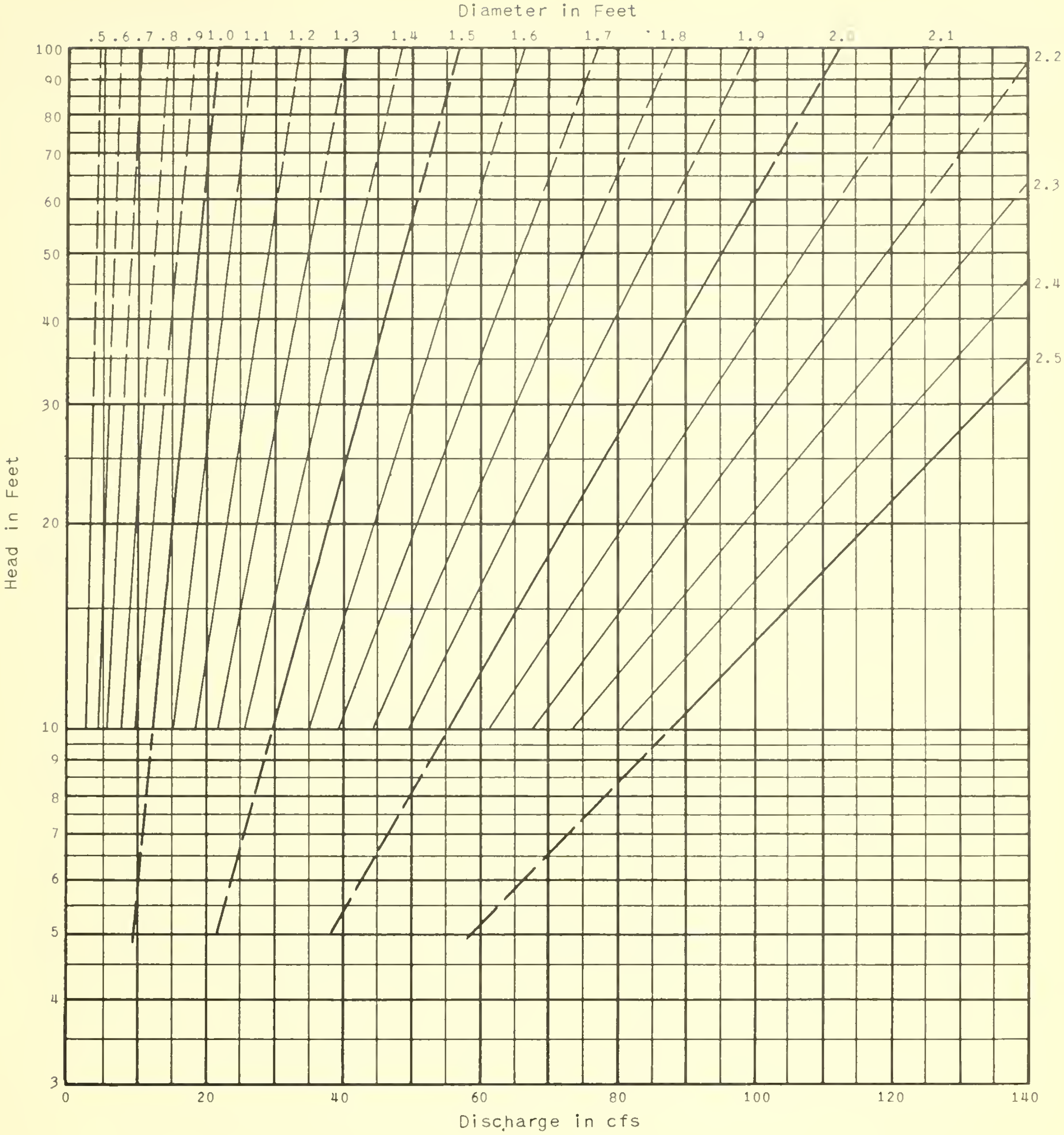


FIGURE NO. 29

DISCHARGE OF CONCRETE PIPE BY DIAMETERS

(LENGTH OF PIPE 15 TIMES HEAD PLUS 20 FEET)

UPPER VERDIGRIS RIVER WATERSHED

KANSAS

REFERENCE: Developed from USDA, SCS, Ft. Worth, Tex. Chart

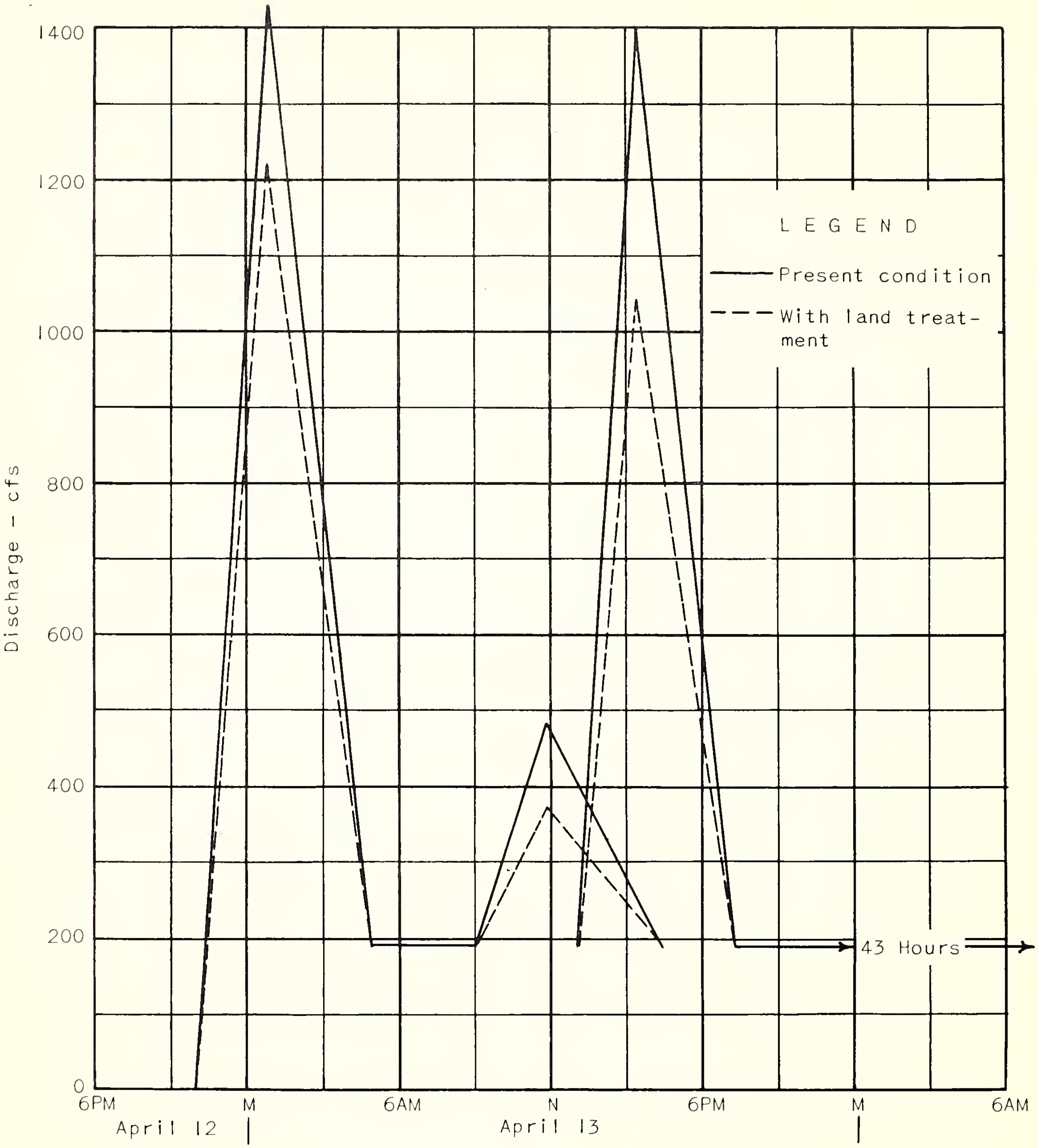


FIGURE NO. 30

COMPUTED HYDROGRAPHS
STORM OF APRIL 12-13, 1947
WITH
WATER RETARDING STRUCTURES
(KANSAS SCS CRITERIA)
SUBAREA NO. 5 AT SECTION C-3
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

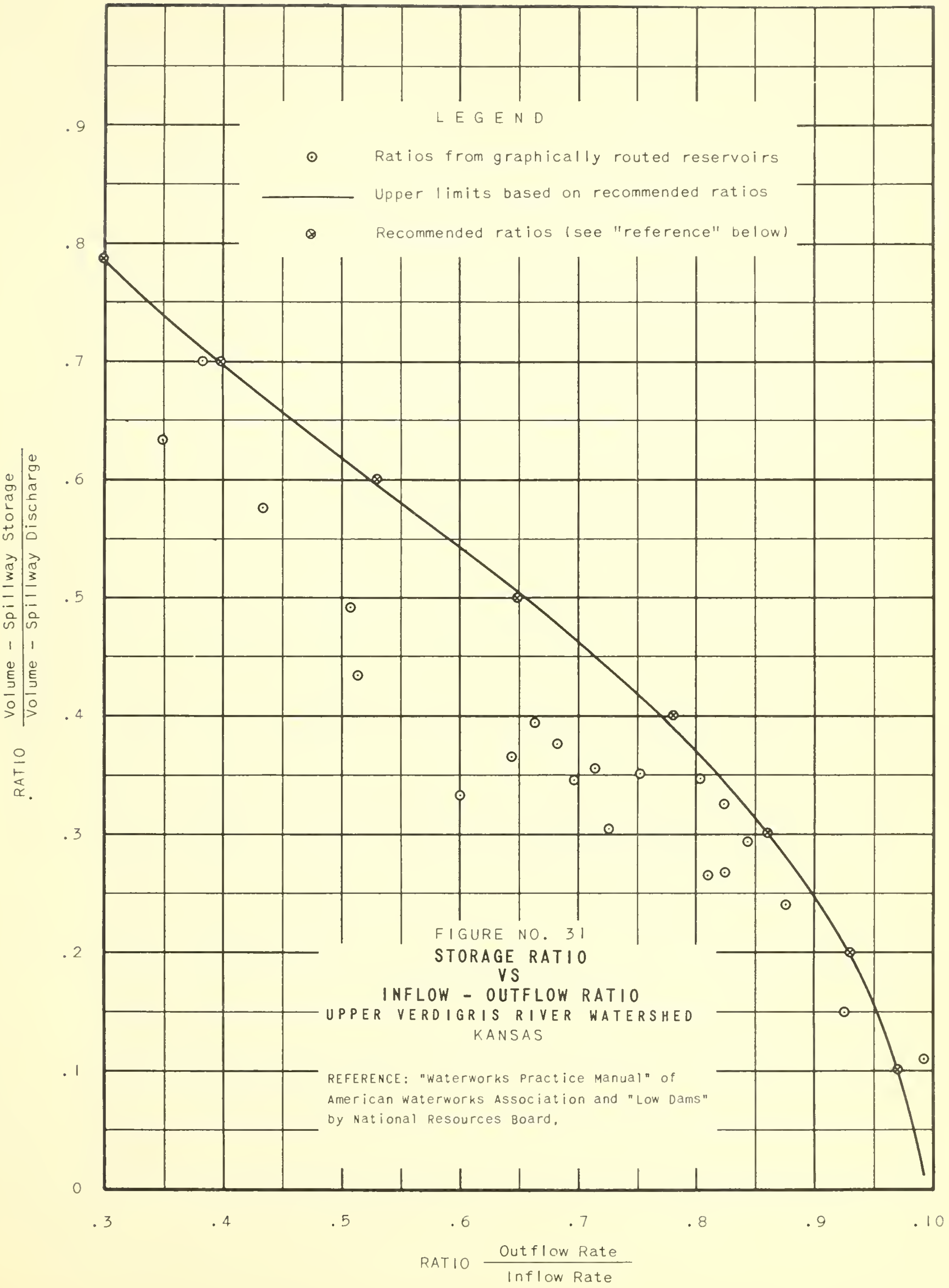


FIGURE NO. 31

STORAGE RATIO

VS

INFLOW - OUTFLOW RATIO

UPPER VERDIGRIS RIVER WATERSHED

KANSAS

REFERENCE: "Waterworks Practice Manual" of American Waterworks Association and "Low Dams" by National Resources Board.

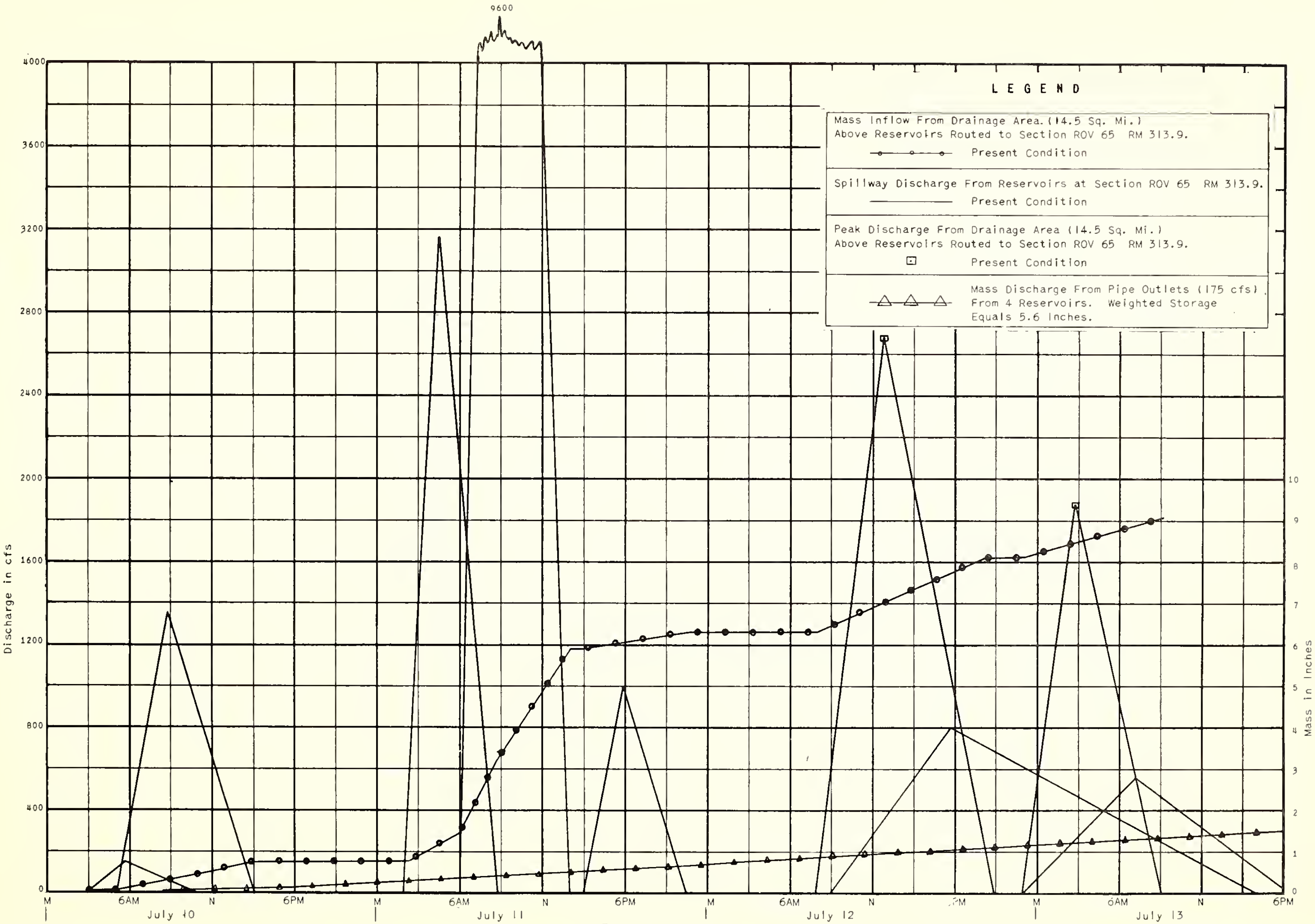


FIGURE NO. 32

MODIFIED TIME CONVERSION ROUTING
OF SPILLWAY DISCHARGE
SUBAREA NO. 9
STORM OF JULY 9 - 13, 1951
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

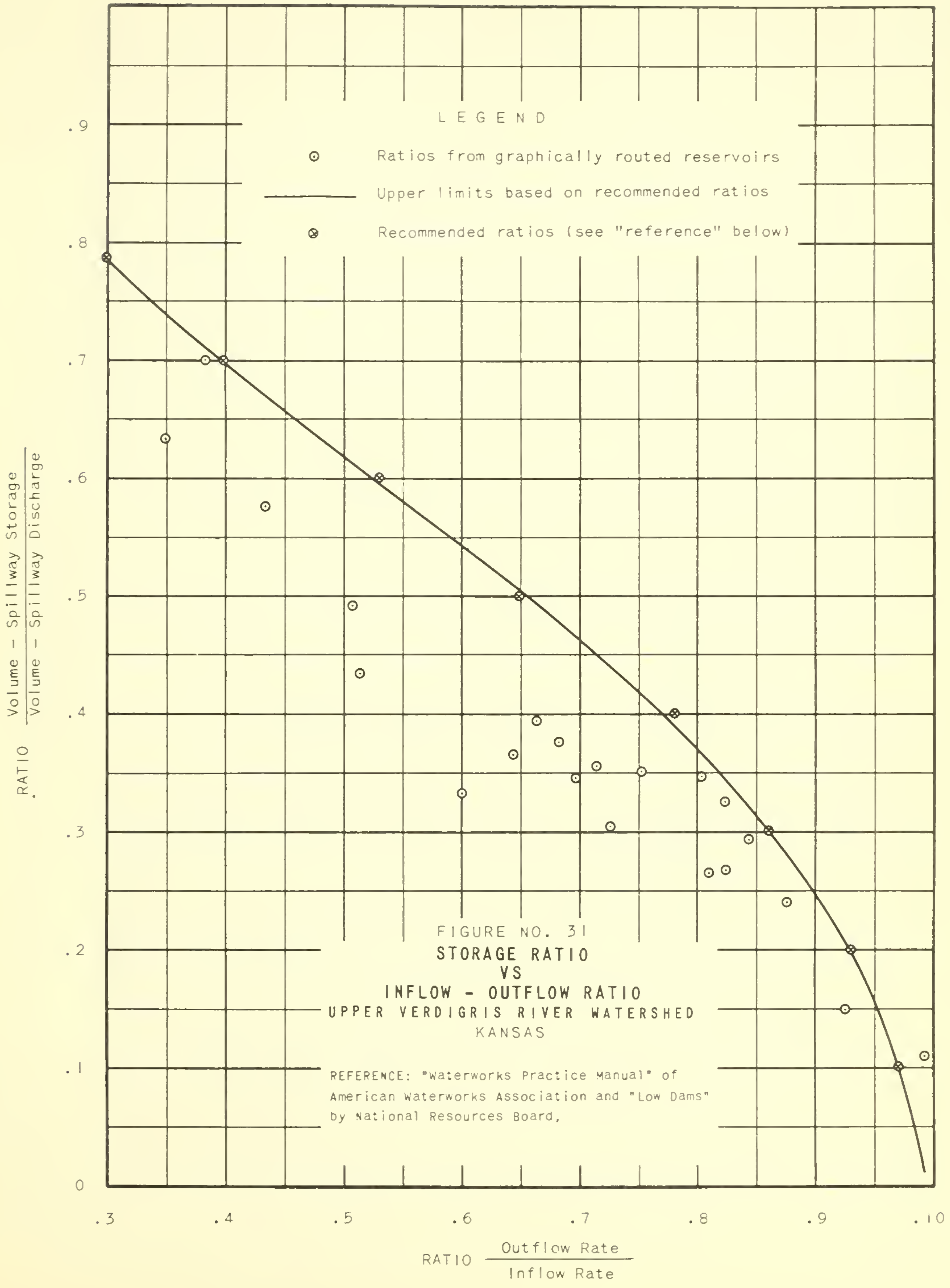


FIGURE NO. 31

STORAGE RATIO
VS
INFLOW - OUTFLOW RATIO
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: "Waterworks Practice Manual" of American Waterworks Association and "Low Dams" by National Resources Board,

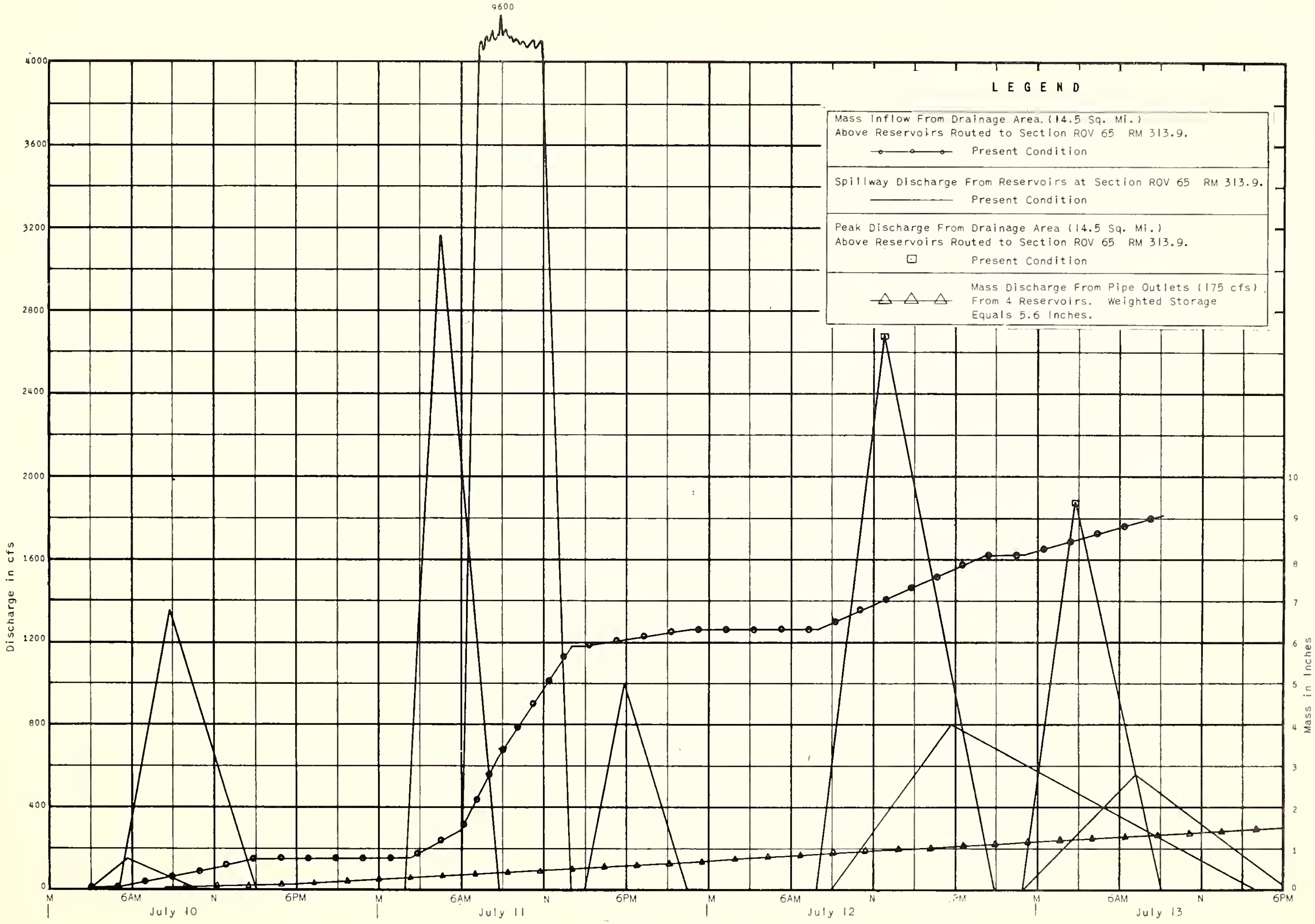


FIGURE NO. 32
MODIFIED TIME CONVERSION ROUTING
OF SPILLWAY DISCHARGE
SUBAREA NO. 9
STORM OF JULY 9 - 13, 1951
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

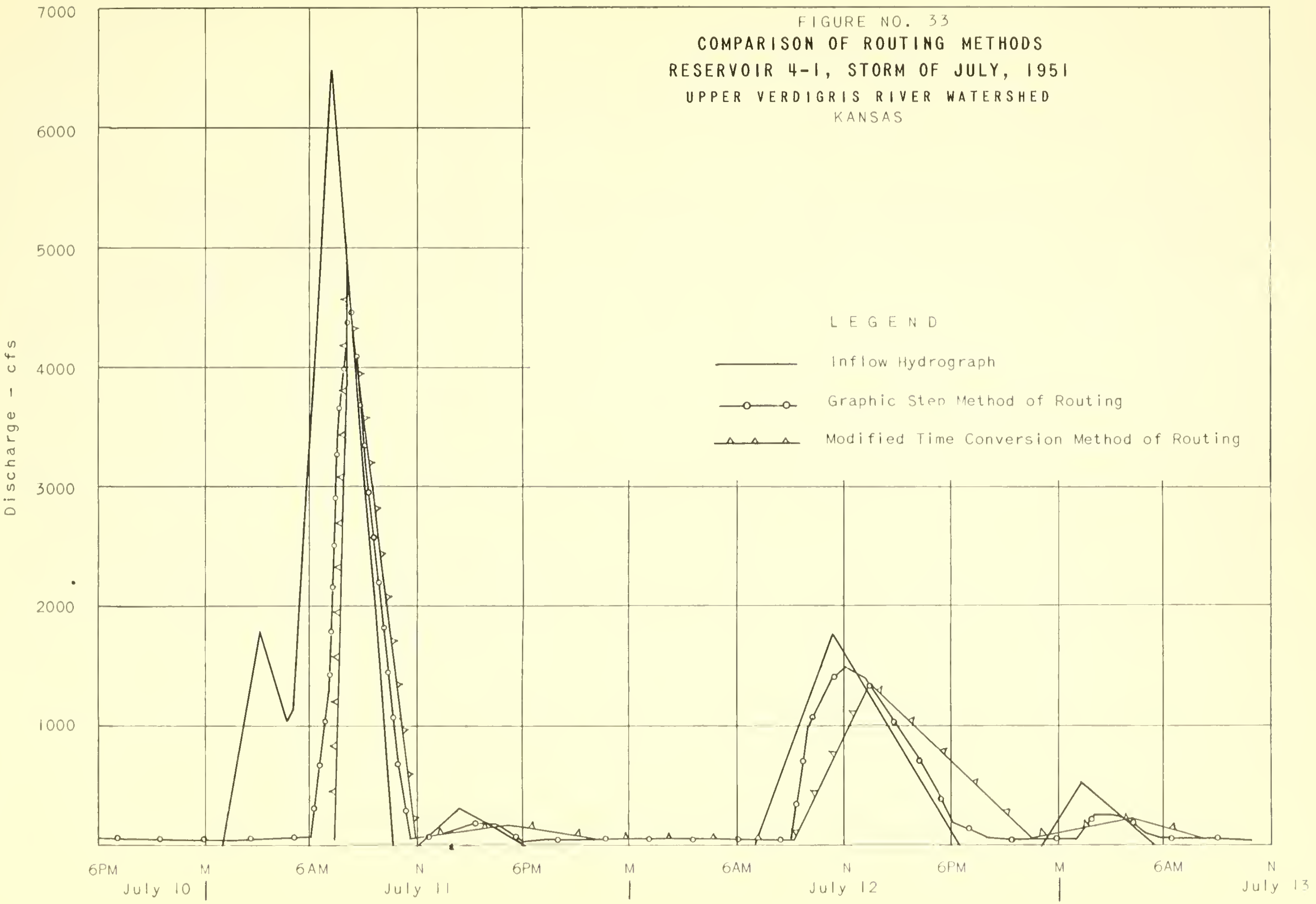


FIGURE NO. 33

COMPARISON OF ROUTING METHODS

RESERVOIR 4-1, STORM OF JULY, 1951

UPPER VERDIGRIS RIVER WATERSHED

KANSAS

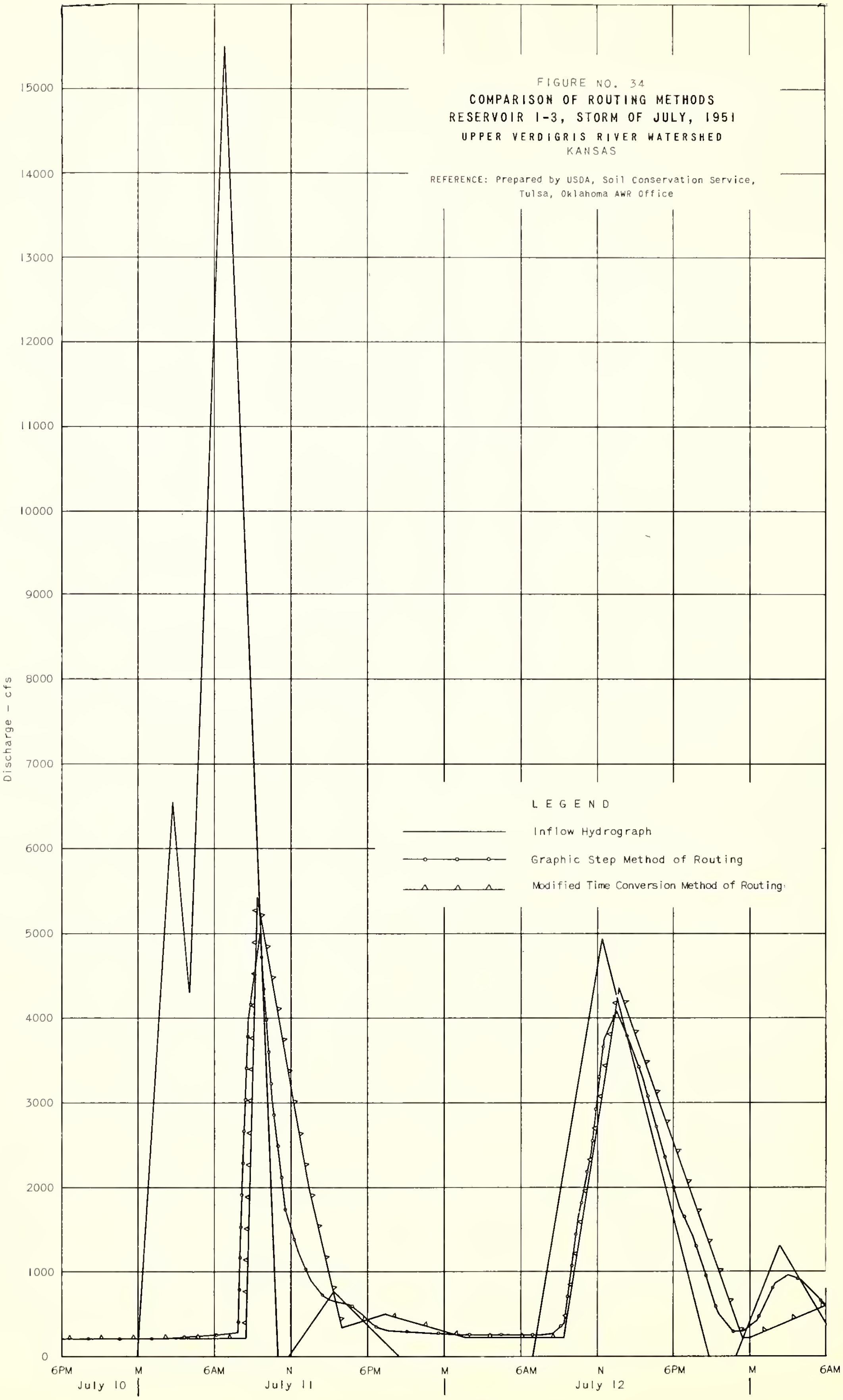


FIGURE NO. 34

COMPARISON OF ROUTING METHODS

RESERVOIR I-3, STORM OF JULY, 1951

UPPER VERDIGRIS RIVER WATERSHED

KANSAS

REFERENCE: Prepared by USDA, Soil Conservation Service,
Tulsa, Oklahoma AWR Office

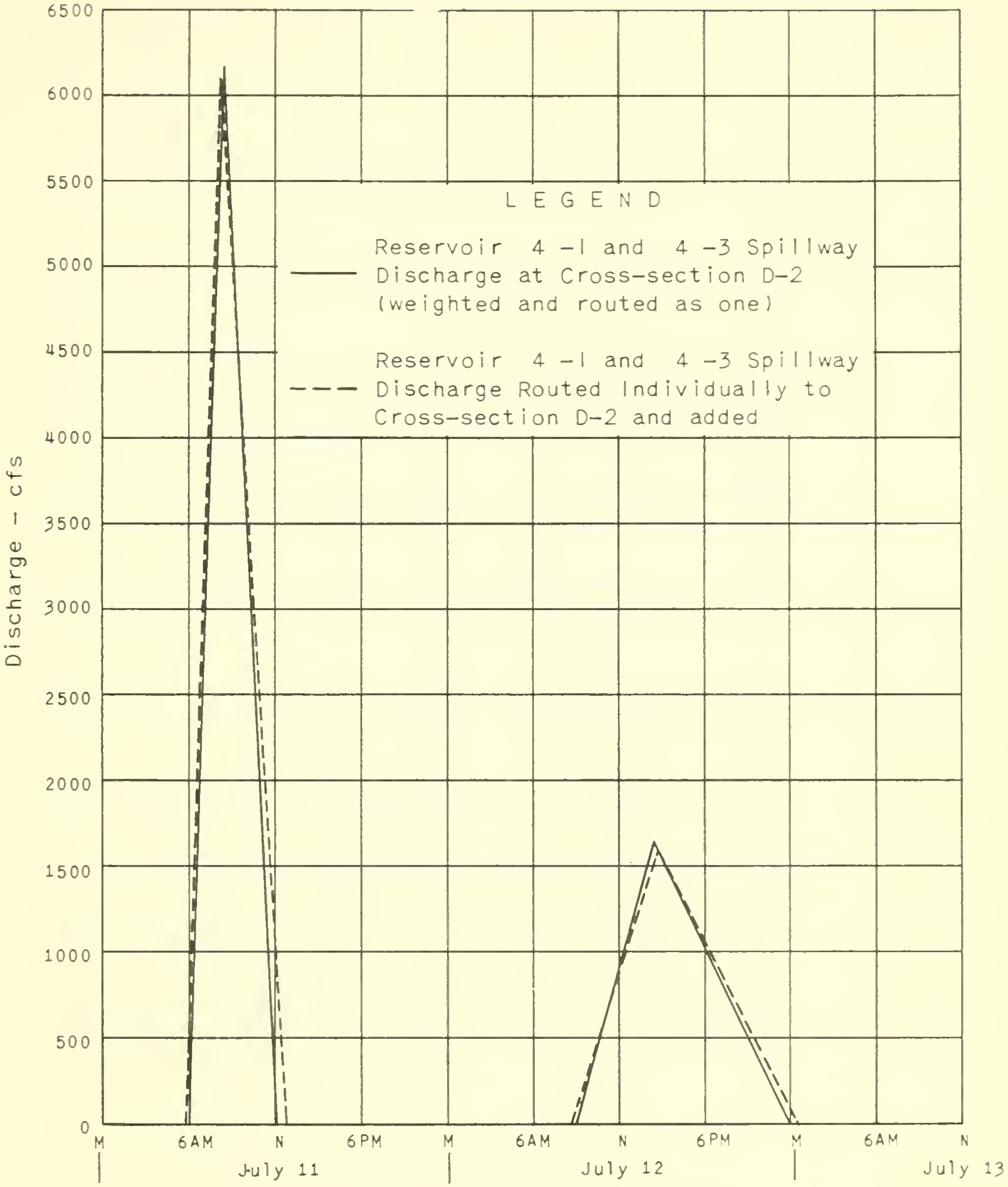


FIGURE NO. 35

COMPARISON OF RESERVOIR ROUTING
PART OF JULY 1951 STORM
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

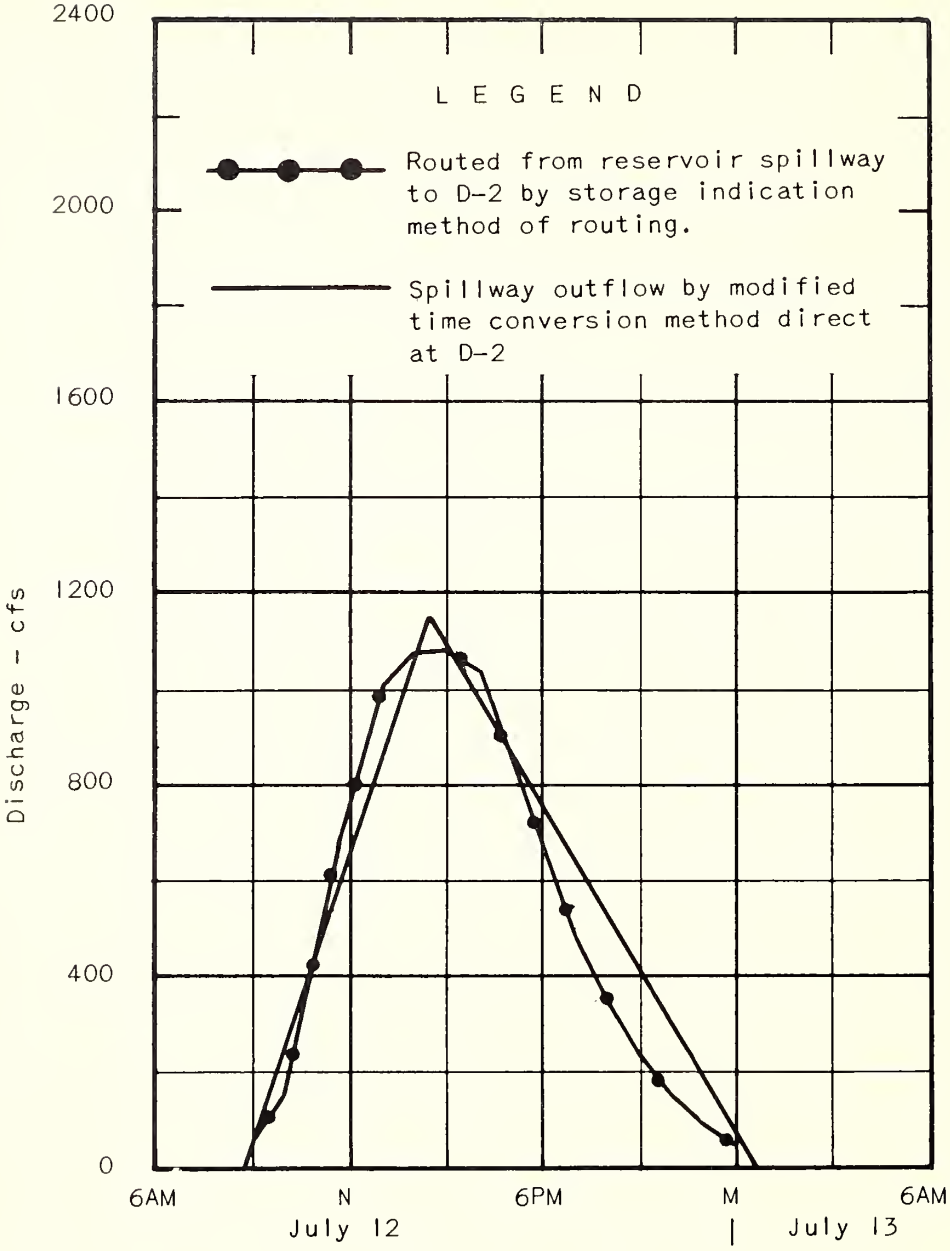


FIGURE NO. 36

COMPARISON OF ROUTING SPILLWAY FLOW FROM RESERVOIR 4-1 TO CROSS-SECTION D-2

(Portion of July, 1951 Storm)

UPPER VERDIGRIS RIVER WATERSHED

KANSAS

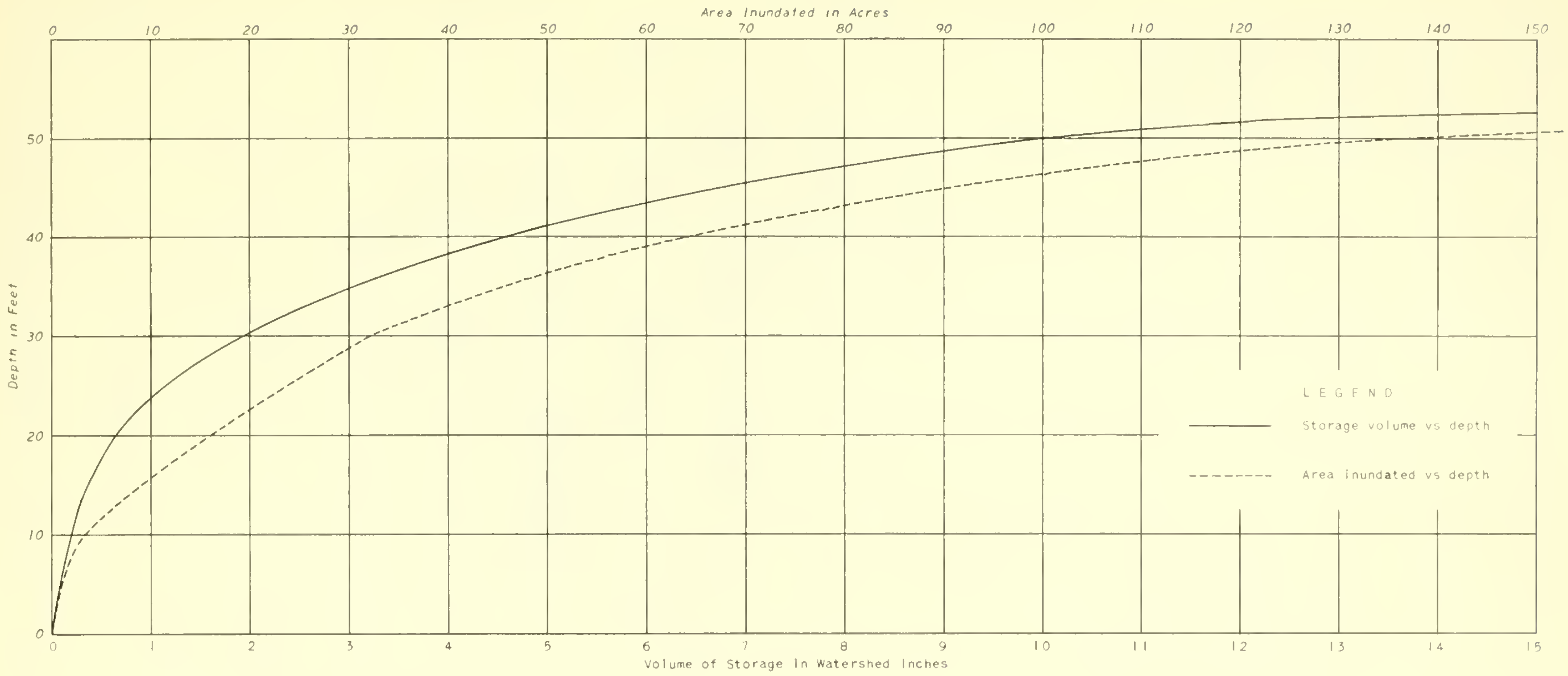


FIGURE NO. 37
RELATIONSHIP OF STORAGE VOLUME VS DEPTH
AND
AREA INUNDATED VS DEPTH
FOR
RESERVOIR NO. 15-5, DRAINAGE AREA 2200 ACRES
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

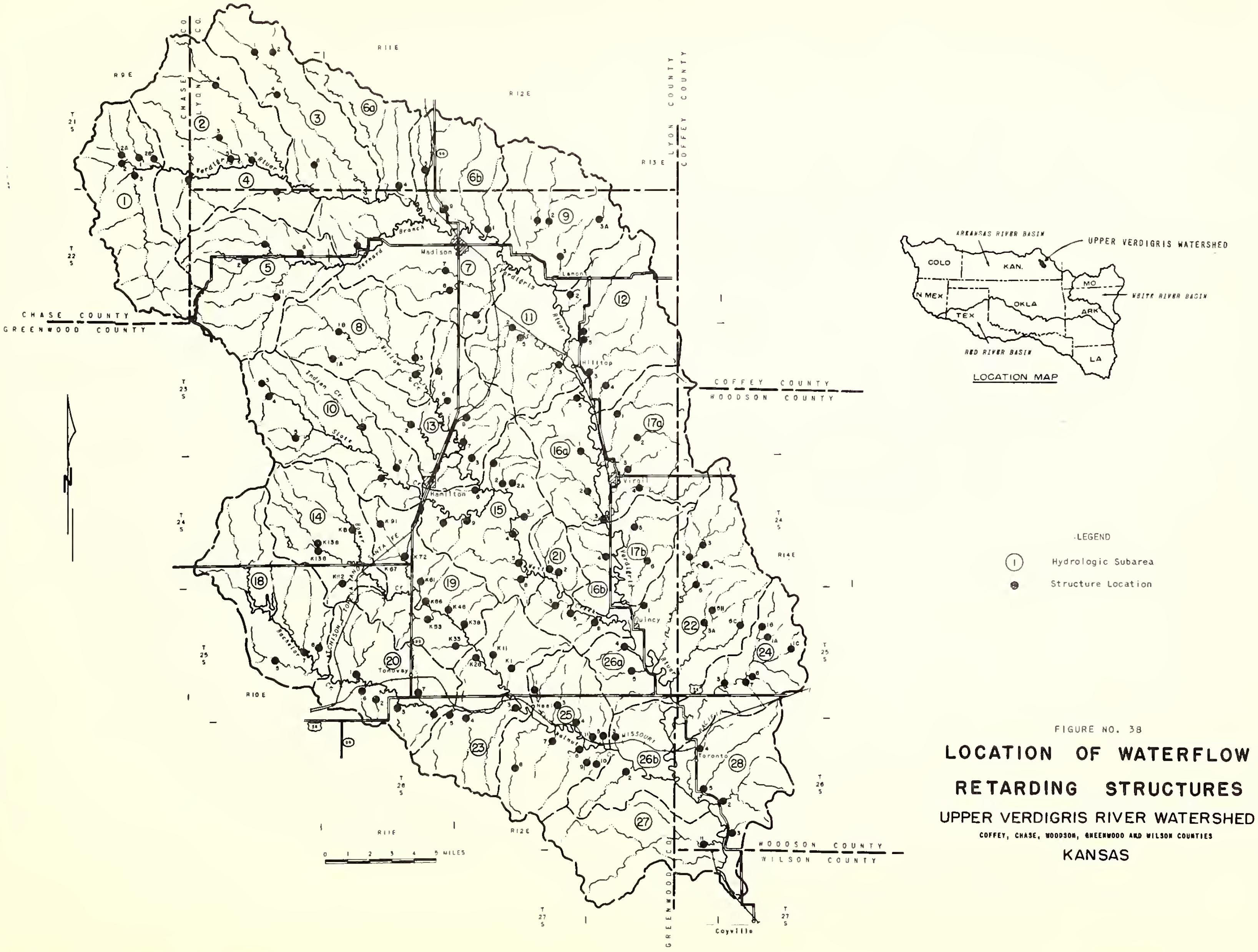


FIGURE NO. 38

LOCATION OF WATERFLOW RETARDING STRUCTURES

UPPER VERDIGRIS RIVER WATERSHED

COFFEY, CHASE, WOODSON, GREENWOOD AND WILSON COUNTIES

KANSAS

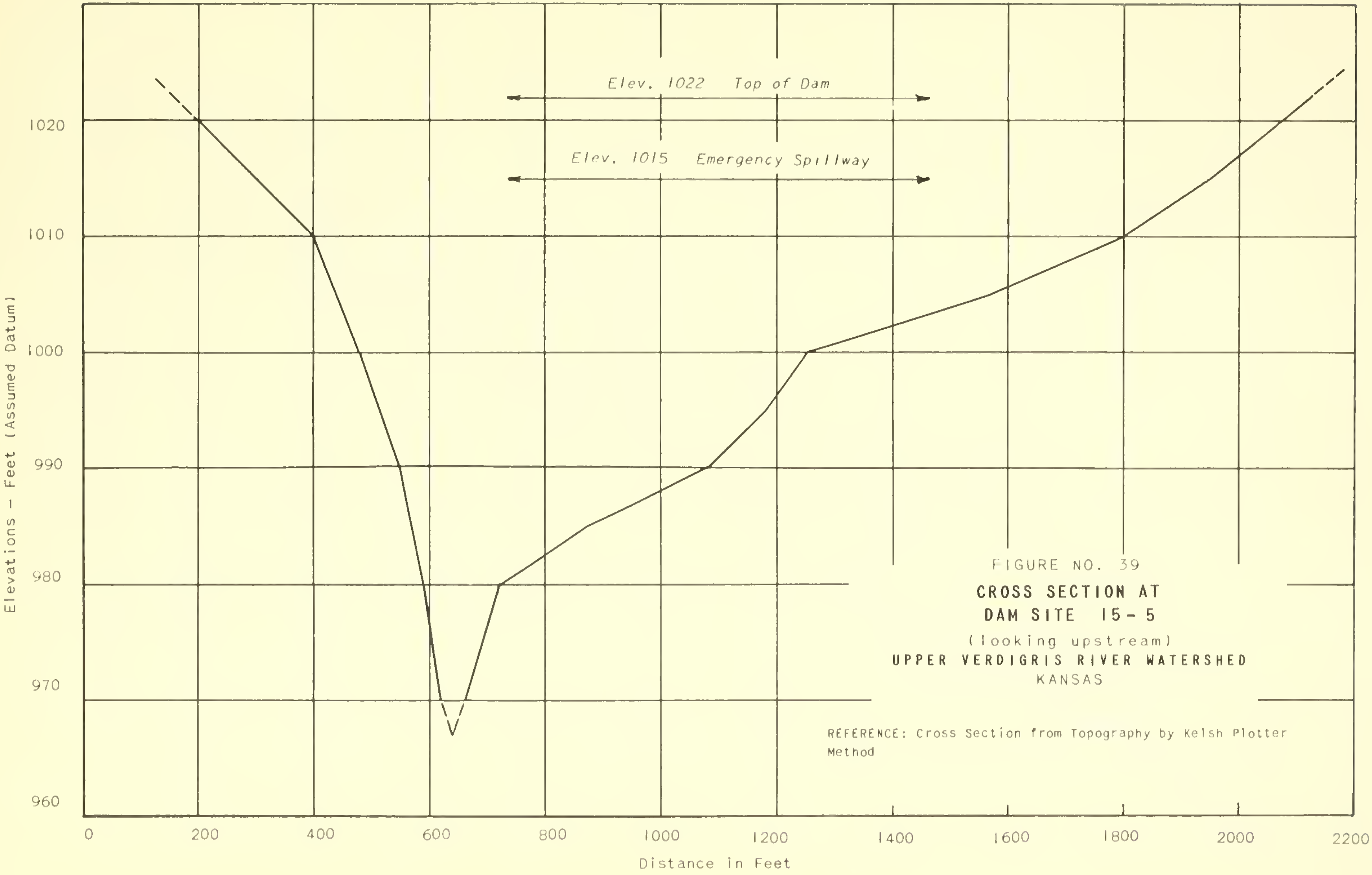


FIGURE NO. 39

CROSS SECTION AT
DAM SITE 15-5
(looking upstream)
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: Cross Section from Topography by Kelsh Plotter Method

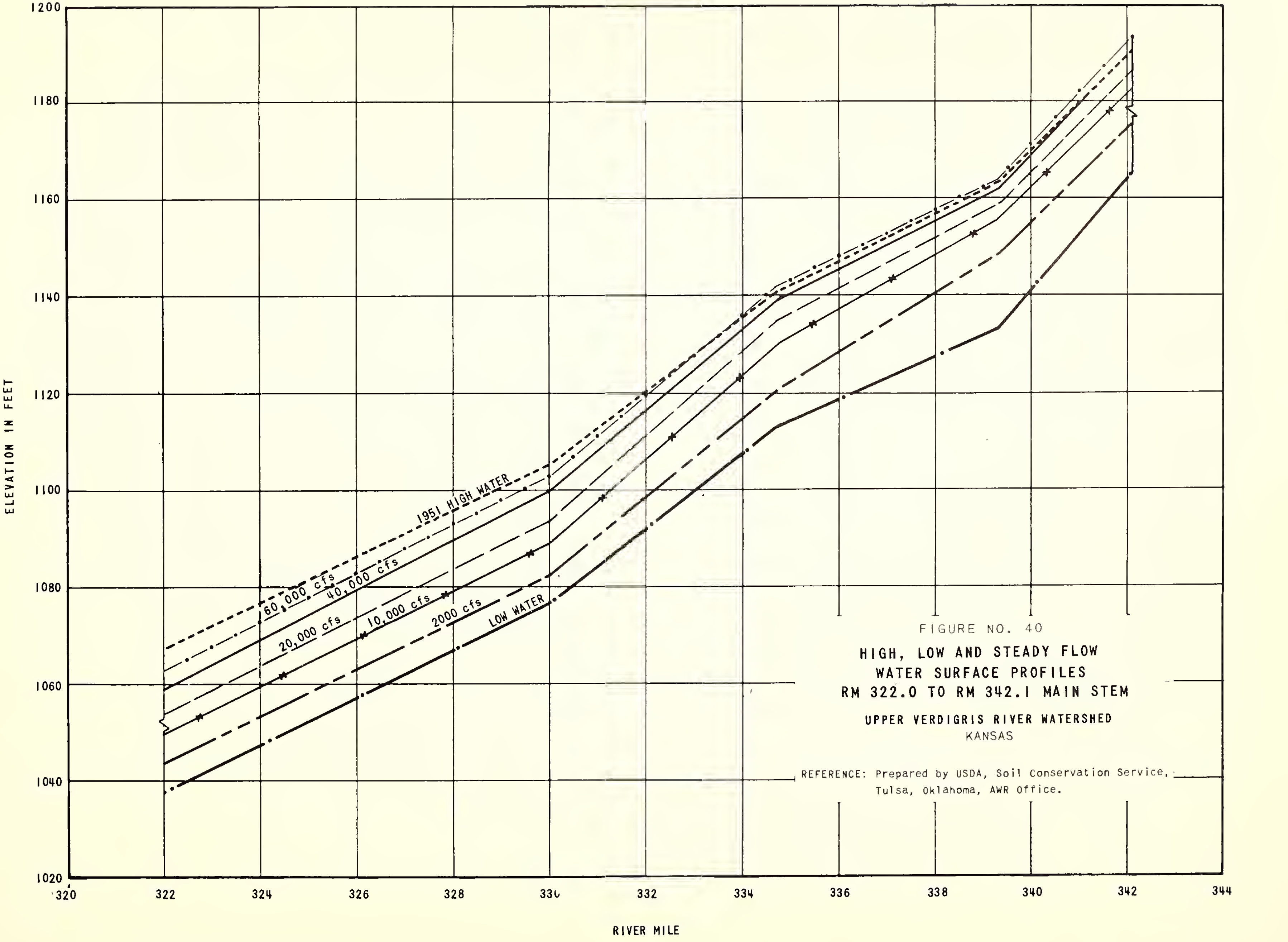
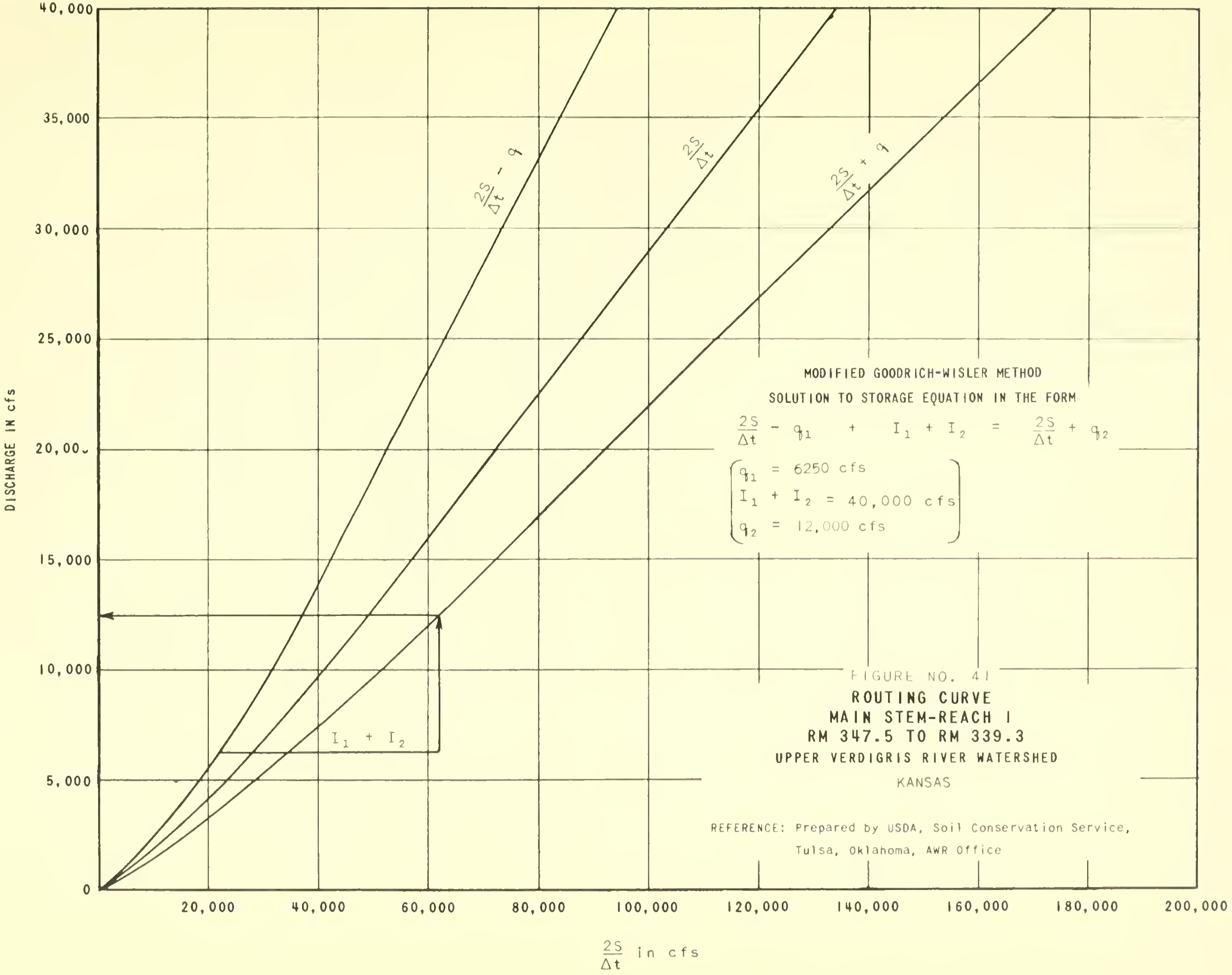


FIGURE NO. 40

HIGH, LOW AND STEADY FLOW WATER SURFACE PROFILES RM 322.0 TO RM 342.1 MAIN STEM

UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: Prepared by USDA, Soil Conservation Service,
Tulsa, Oklahoma, AWR Office.



MODIFIED GOODRICH-WISLER METHOD

SOLUTION TO STORAGE EQUATION IN THE FORM

$$\frac{2S}{\Delta t} - q_1 + I_1 + I_2 = \frac{2S}{\Delta t} + q_2$$

$$\left(\begin{array}{l} q_1 = 6250 \text{ cfs} \\ I_1 + I_2 = 40,000 \text{ cfs} \\ q_2 = 12,000 \text{ cfs} \end{array} \right)$$

FIGURE NO. 41

ROUTING CURVE
MAIN STEM-REACH I
RM 347.5 TO RM 339.3
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: Prepared by USDA, Soil Conservation Service,
Tulsa, Oklahoma, AWR Office

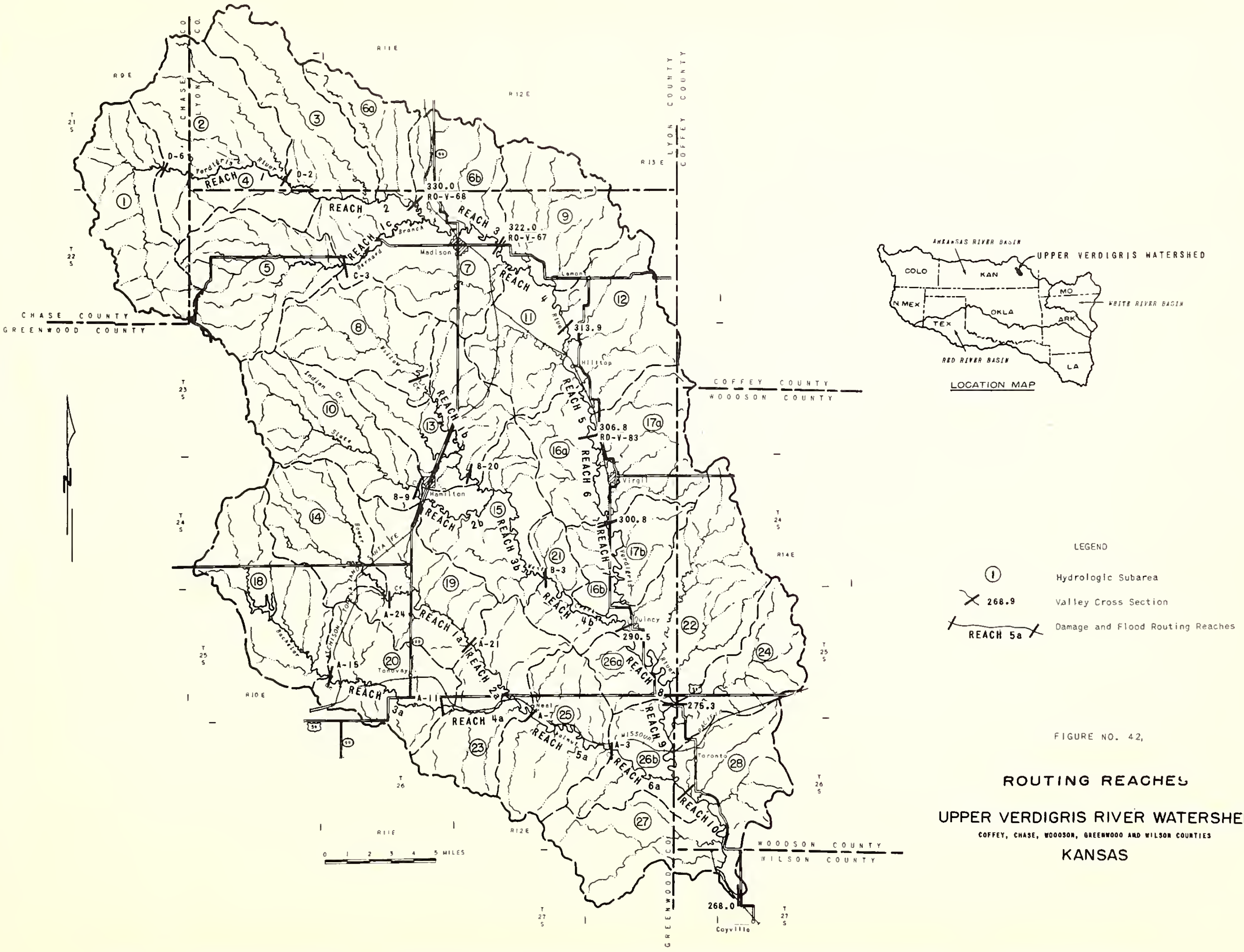


FIGURE NO. 42,

ROUTING REACHES

UPPER VERDIGRIS RIVER WATERSHED

COFFEY, CHASE, WOODSON, GREENWOOD AND WILSON COUNTIES

KANSAS

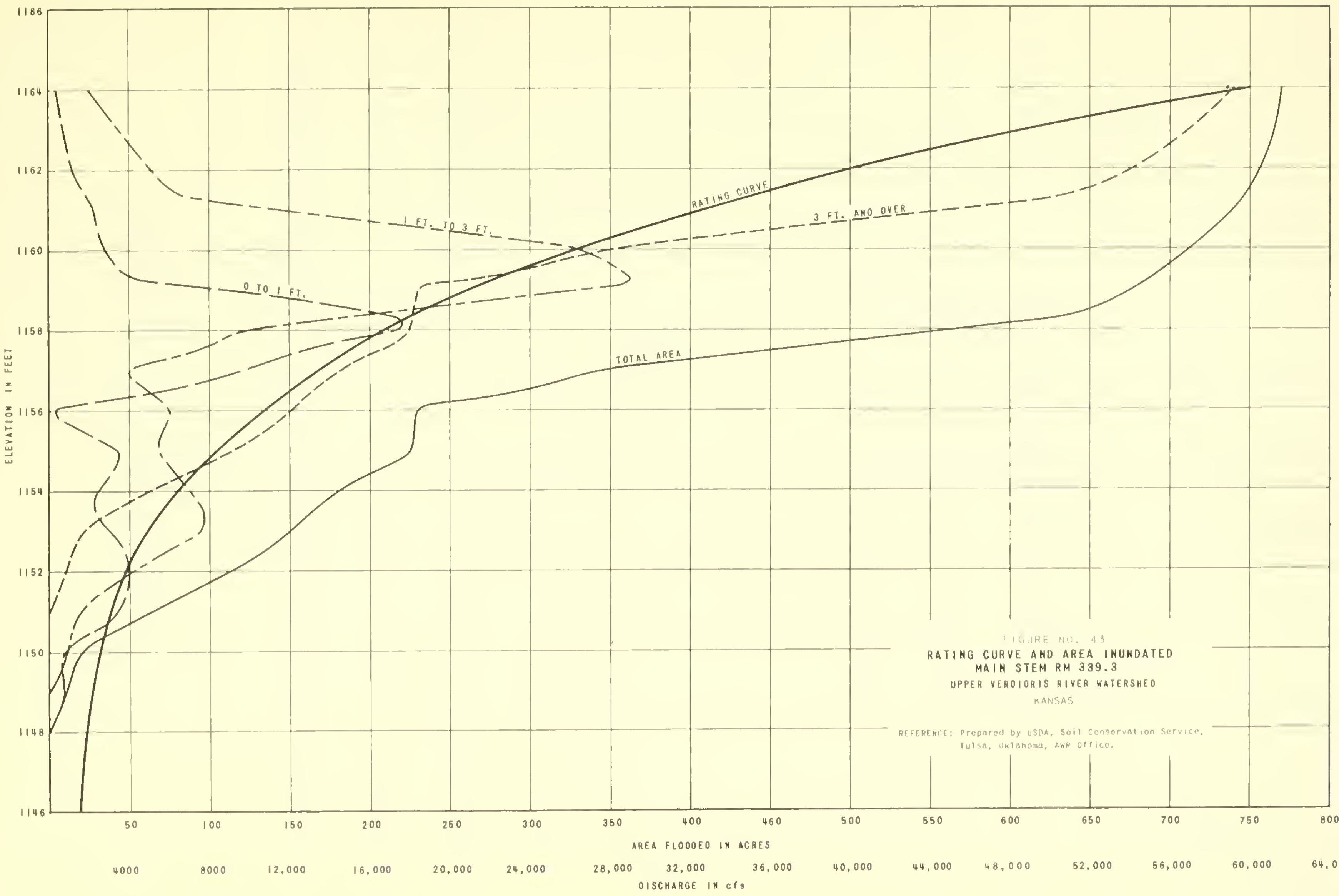


FIGURE NO. 43
RATING CURVE AND AREA INUNDATED
MAIN STEM RM 339.3
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: Prepared by USDA, Soil Conservation Service,
Tulsa, Oklahoma, AWR Office.

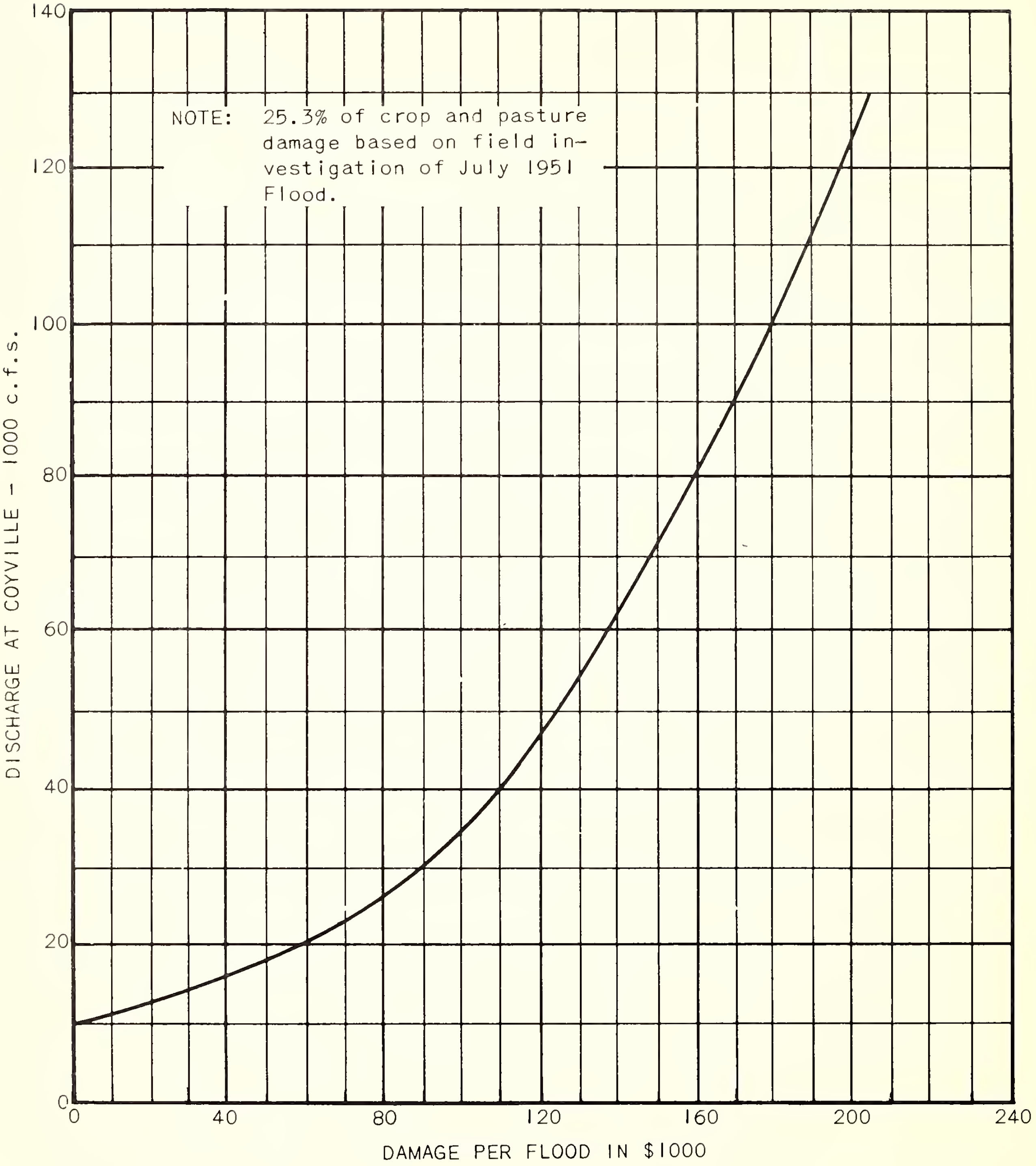


FIGURE NO. 44

OTHER AGRICULTURAL DAMAGE

UPPER VERDIGRIS RIVER WATERSHED

KANSAS

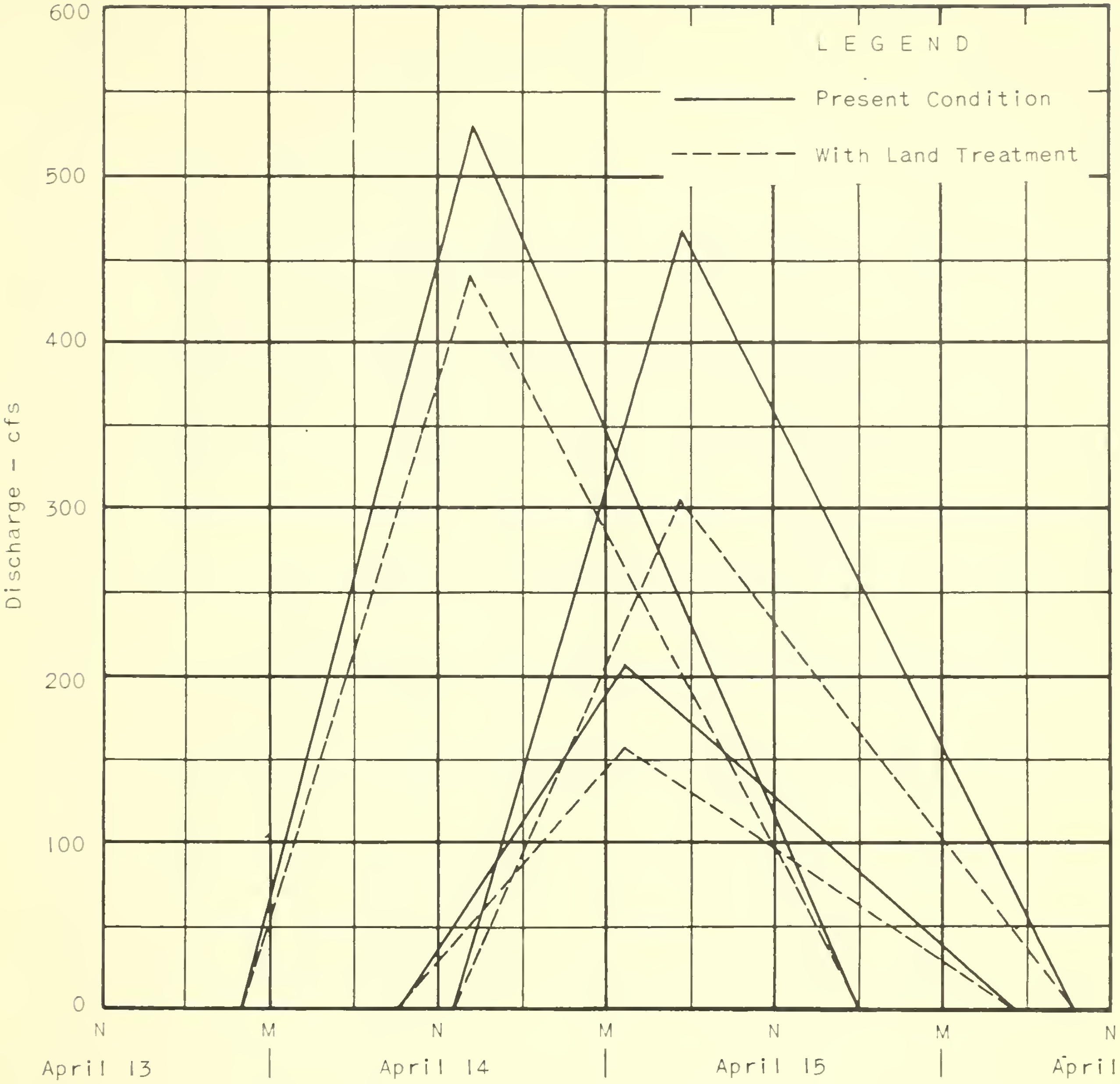


FIGURE NO. 45

COMPUTED HYDROGRAPHS

STORM OF APRIL 12-16, 1947

SUBAREA NUMBER . 5 ROUTED TO COYVILLE, KANSAS-GAGE

UPPER VERDIGRIS RIVER WATERSHED

KANSAS

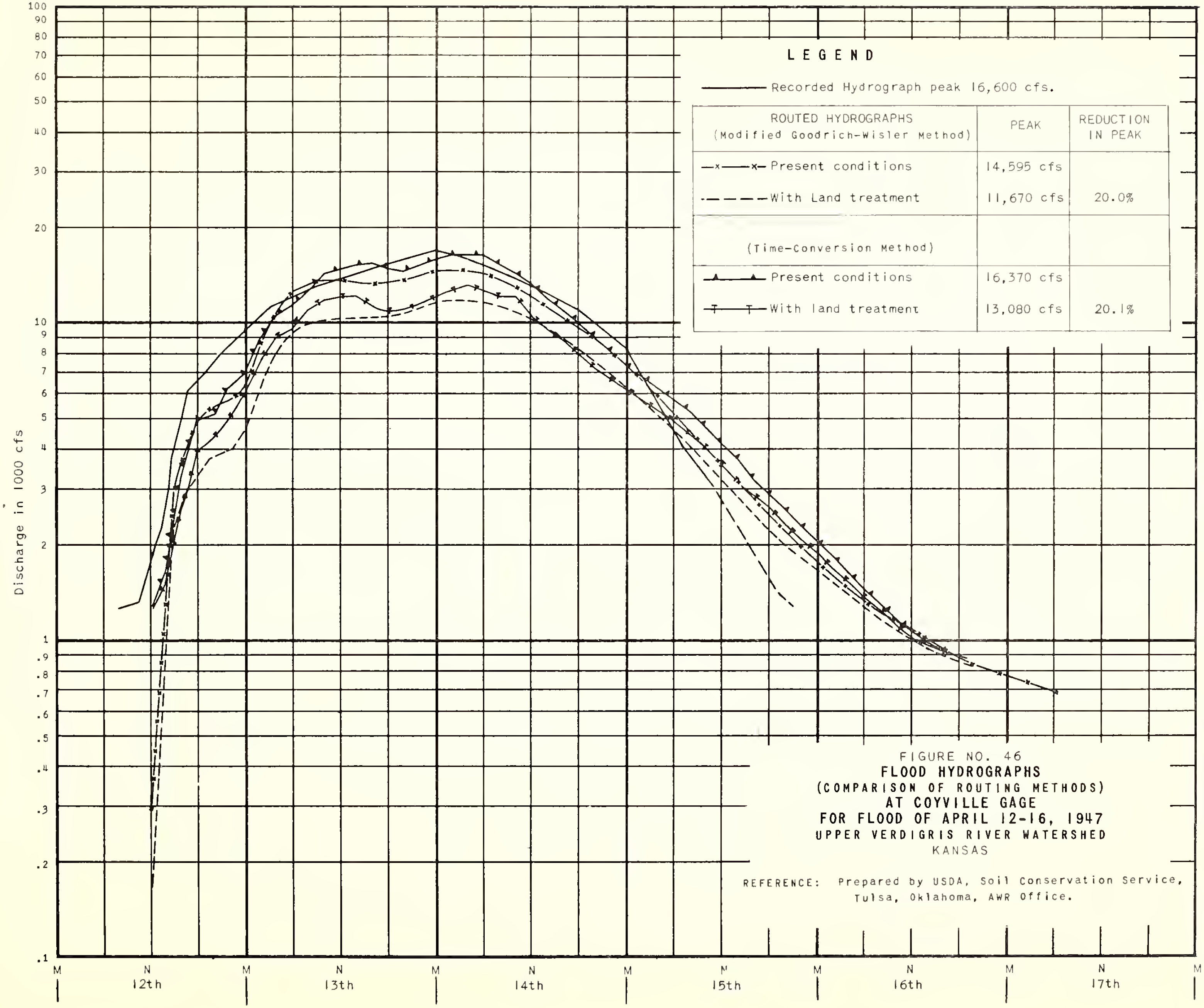


FIGURE NO. 46
FLOOD HYDROGRAPHS
(COMPARISON OF ROUTING METHODS)
AT COYVILLE GAGE
FOR FLOOD OF APRIL 12-16, 1947
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: Prepared by USDA, Soil Conservation Service, Tulsa, Oklahoma, AWR Office.

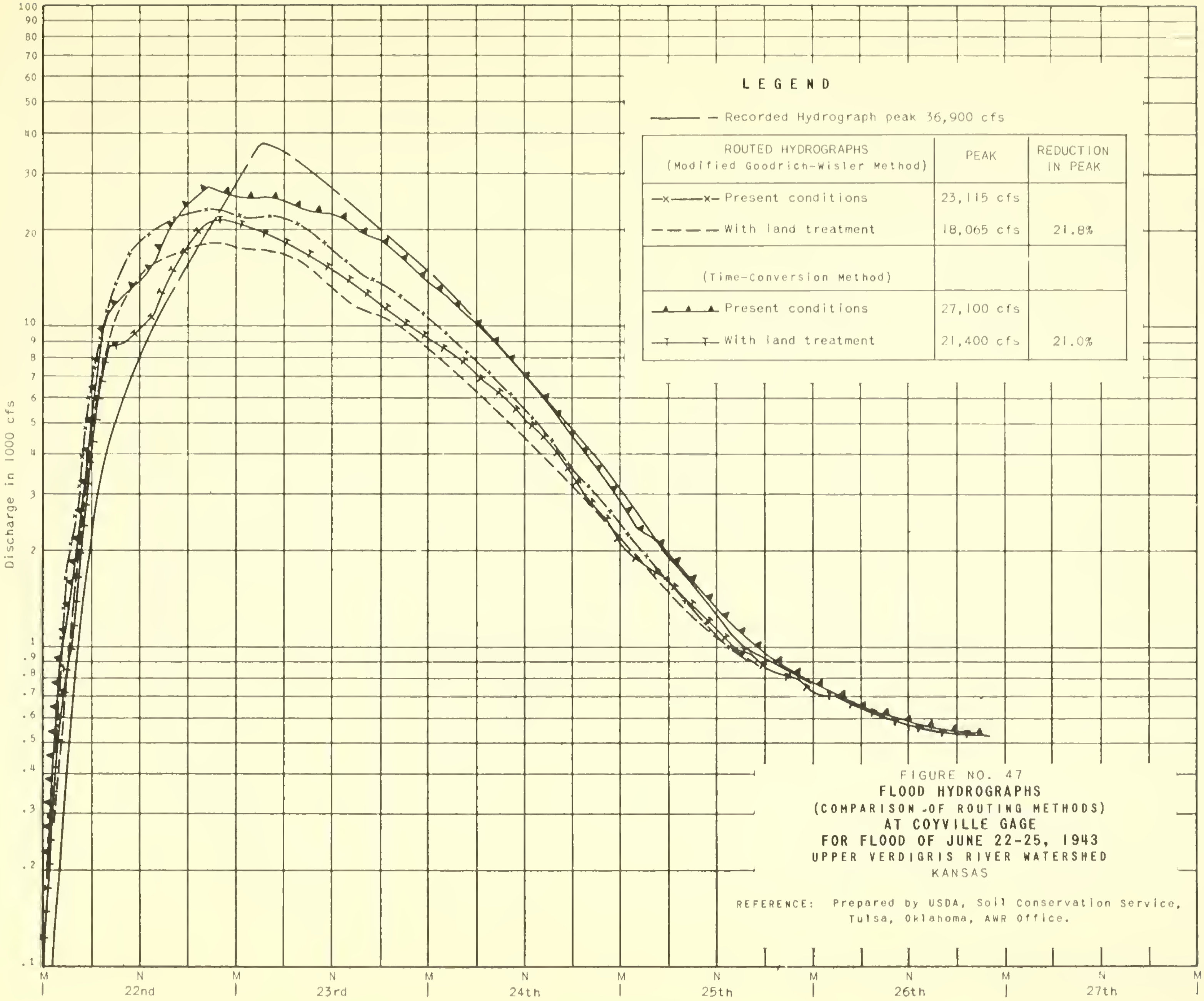


FIGURE NO. 47

FLOOD HYDROGRAPHS
(COMPARISON OF ROUTING METHODS)
AT COYVILLE GAGE
FOR FLOOD OF JUNE 22-25, 1943
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: Prepared by USDA, Soil Conservation Service, Tulsa, Oklahoma, AWR Office.

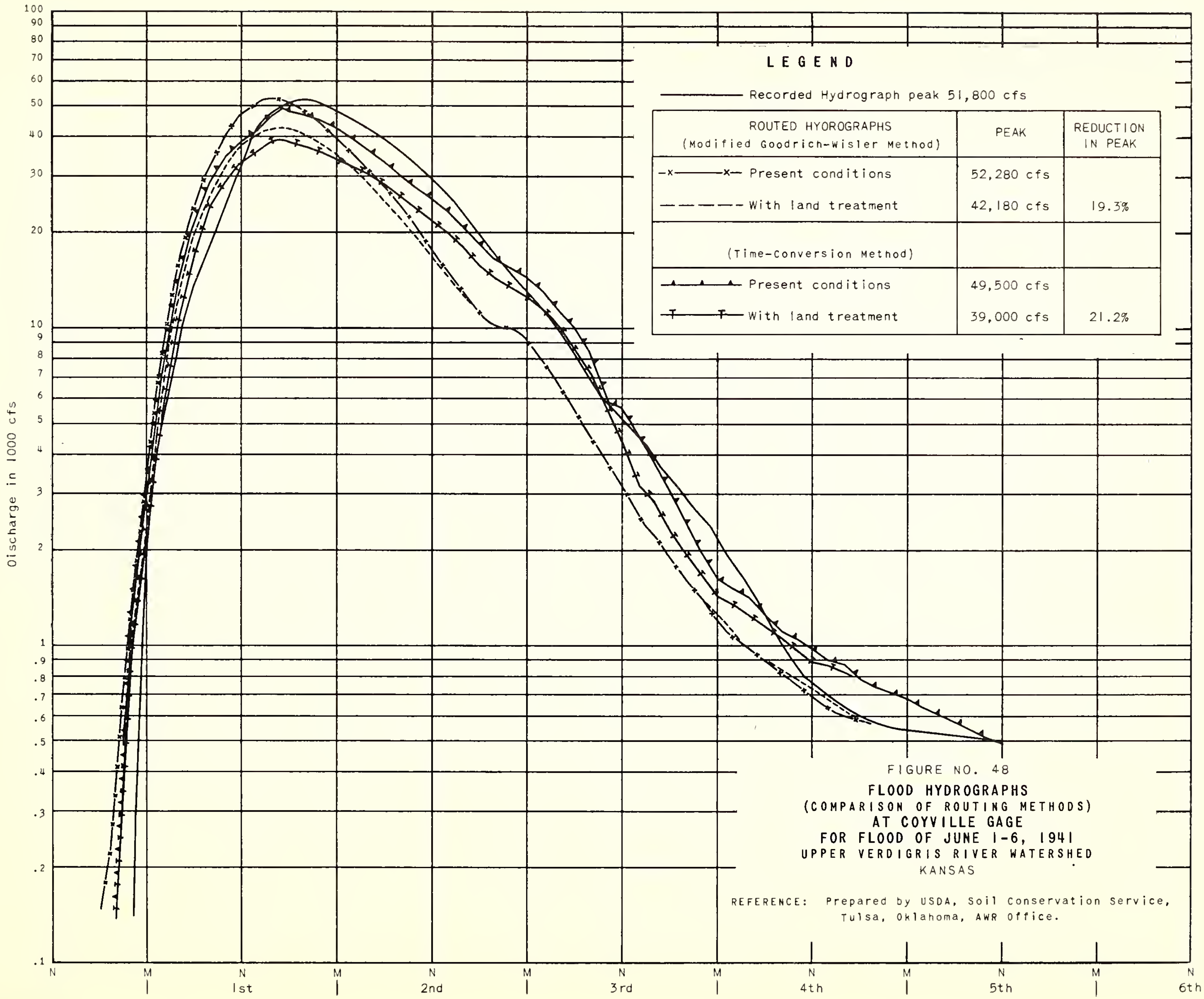


FIGURE NO. 48

FLOOD HYDROGRAPHS
(COMPARISON OF ROUTING METHODS)
AT COYVILLE GAGE
FOR FLOOD OF JUNE 1-6, 1941
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: Prepared by USDA, Soil Conservation Service, Tulsa, Oklahoma, AWR Office.

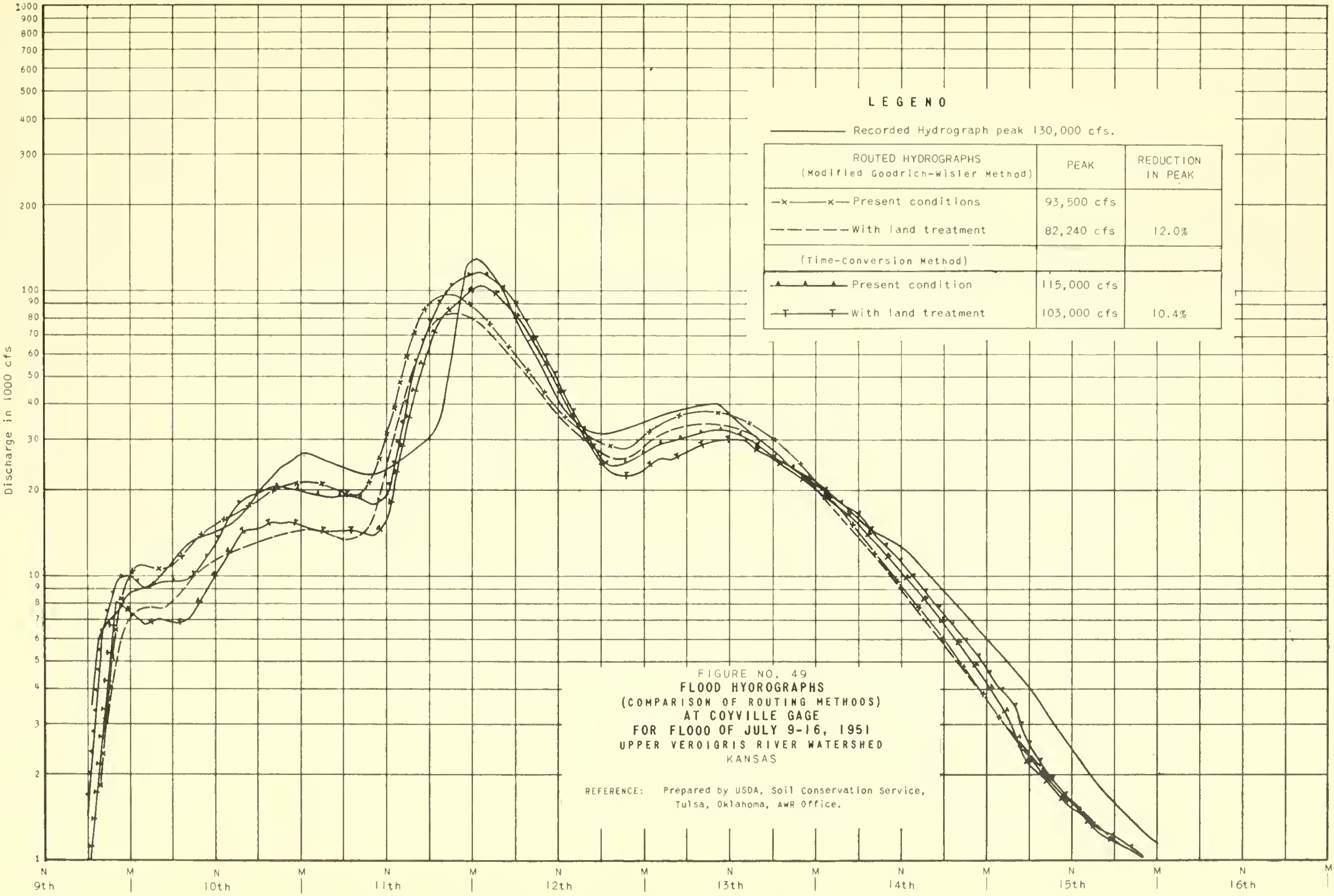


FIGURE NO. 49
FLOOD HYDROGRAPHS
(COMPARISON OF ROUTING METHODS)
AT COYVILLE GAGE
FOR FLOOD OF JULY 9-16, 1951
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: Prepared by USDA, Soil Conservation Service, Tulsa, Oklahoma, AWR Office.

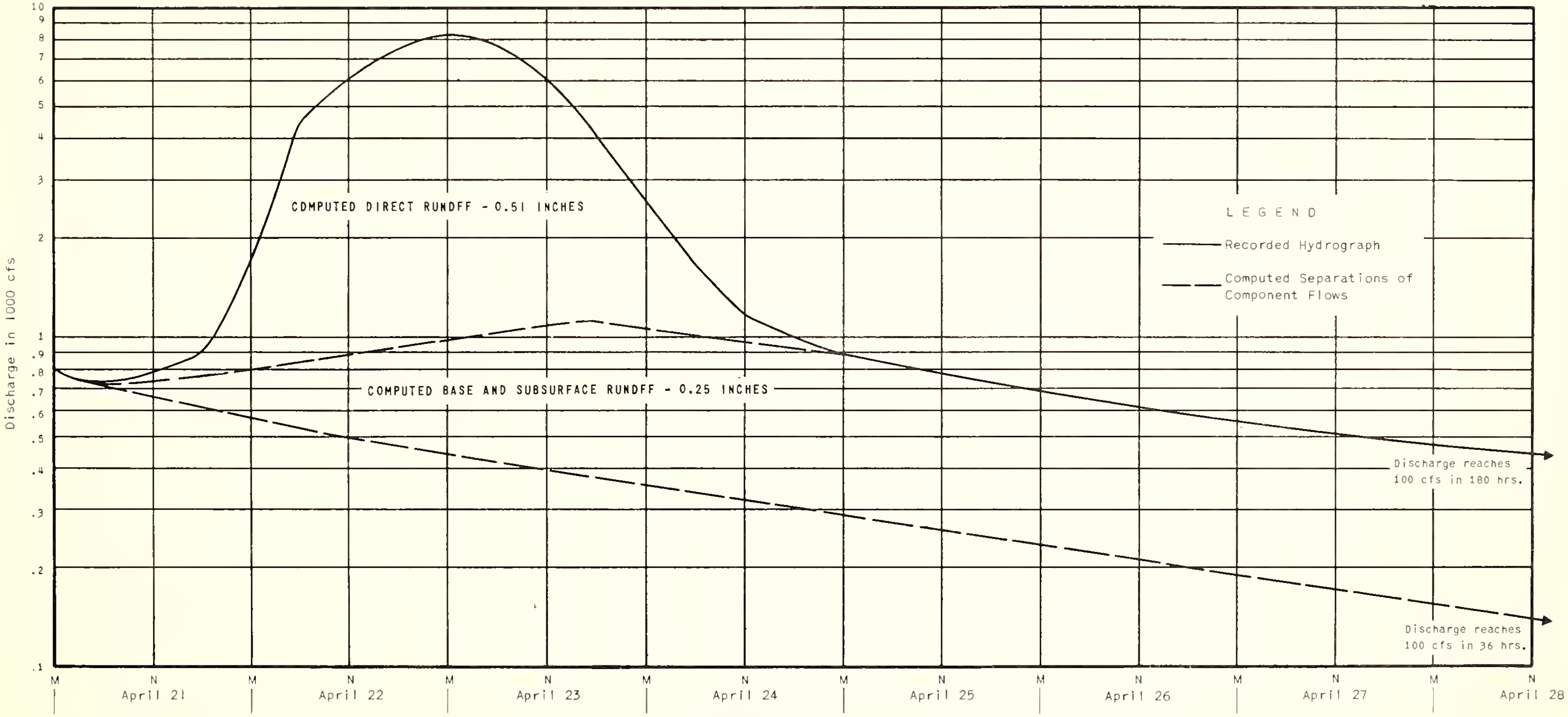


FIGURE NO. 50

COMPONENT FLOWS
APRIL 21 TO APRIL 28, 1952
RECORDED HYDROGRAPH, COYVILLE, KANSAS
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: Recorded Hydrograph developed from USGS Records.

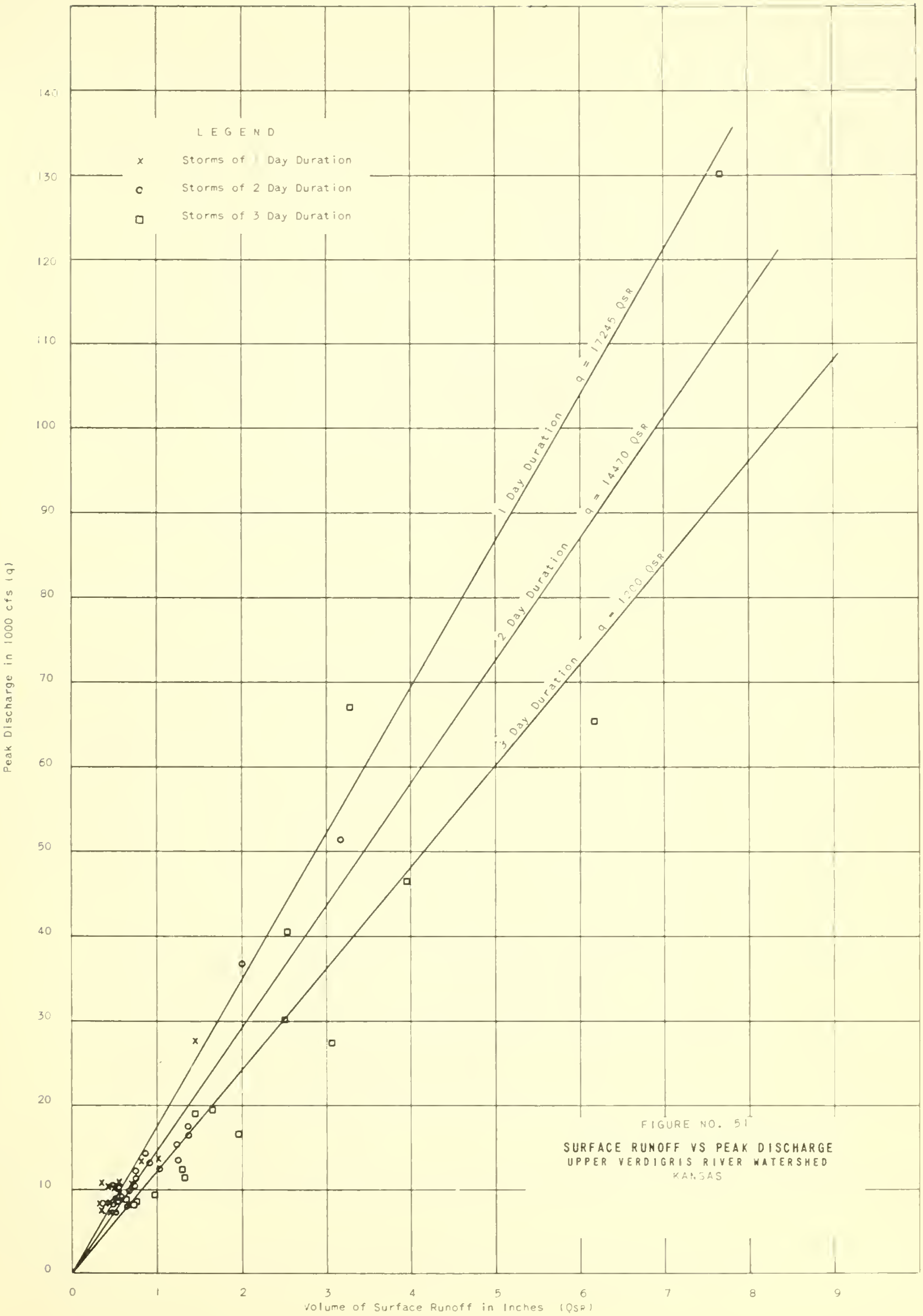


FIGURE NO. 51

SURFACE RUNOFF VS PEAK DISCHARGE
UPPER VERDIGRIS RIVER WATERSHED
KANSAS

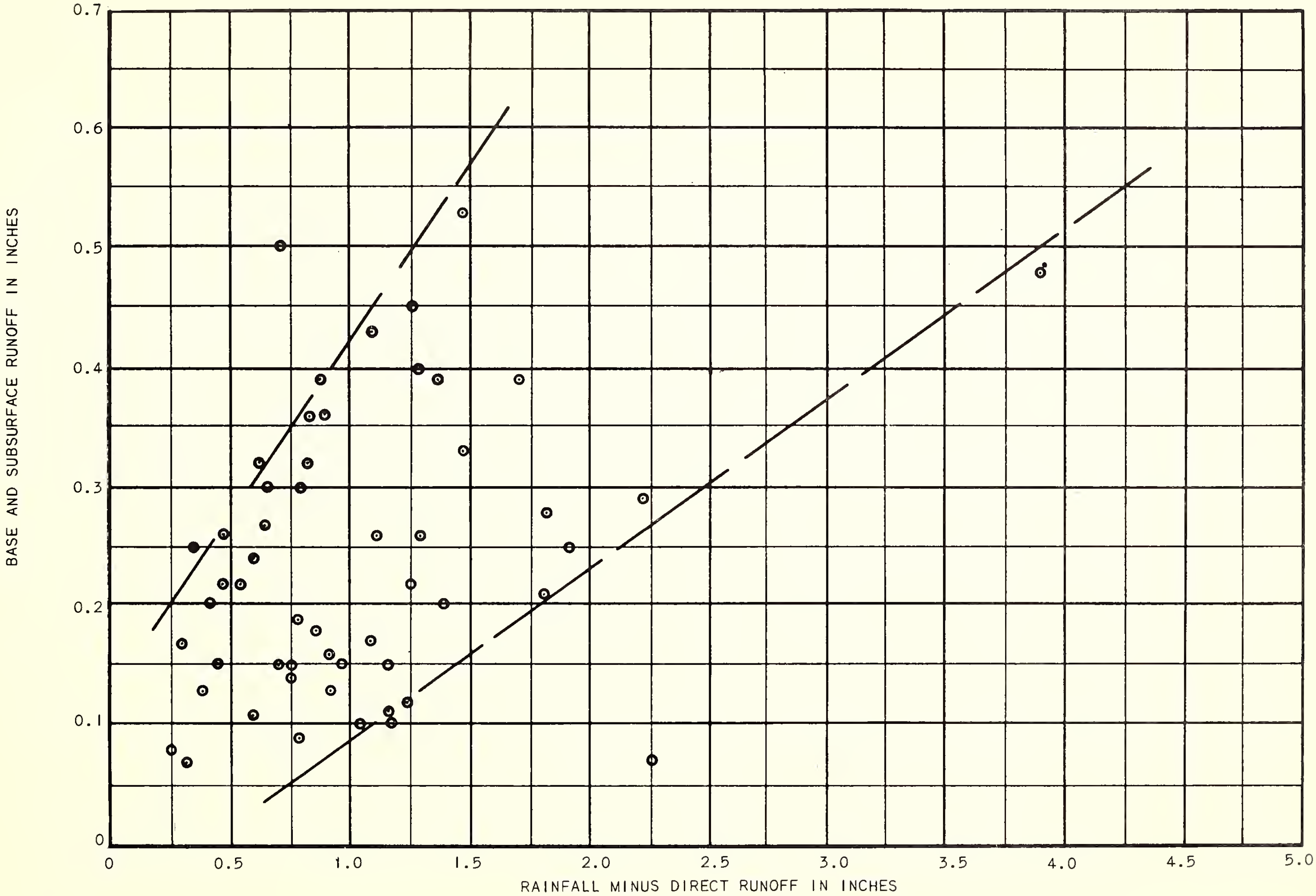


FIGURE NO. 52

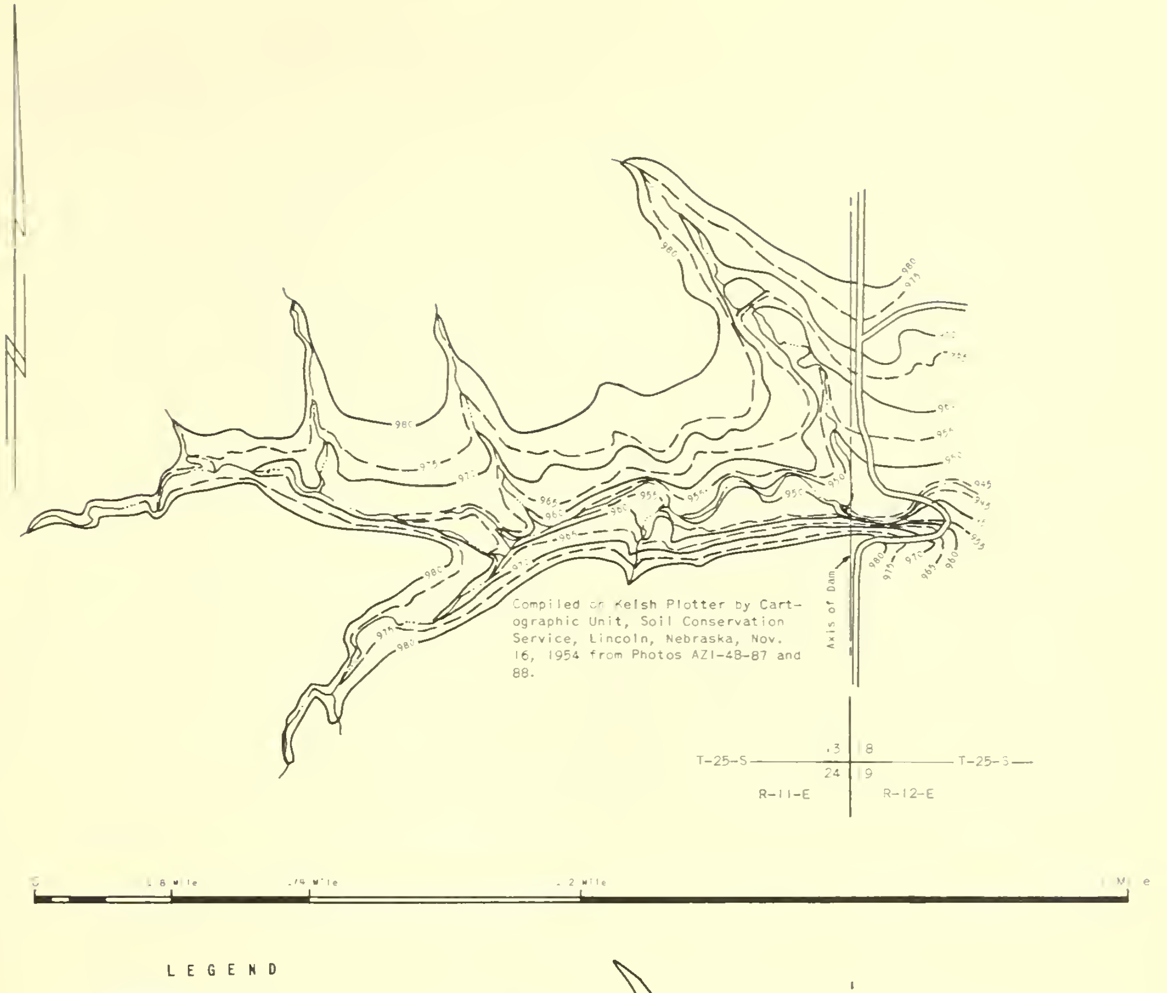
RAINFALL MINUS DIRECT RUNOFF

VS

BASE AND SUBSURFACE RUNOFF

UPPER VERDIGRIS RIVER WATERSHED

KANSAS



Compiled on Kelsh Plotter by Cartographic Unit, Soil Conservation Service, Lincoln, Nebraska, Nov. 16, 1954 from Photos AZI-48-87 and 88.

Plane Table Map surveyed in 1951 by Kansas State Board of Agriculture, Division of Water Resources.

FIGURE NO. 53

COMPARISON OF TOPOGRAPHIC MAPS OF SITE 19-K33

SECTIONS 13 AND 24, T-25-S, R-11-E, AND SECTION 18, T-25-S, R-12-E

UPPER VERDIGRIS RIVER WATERSHED

KANSAS

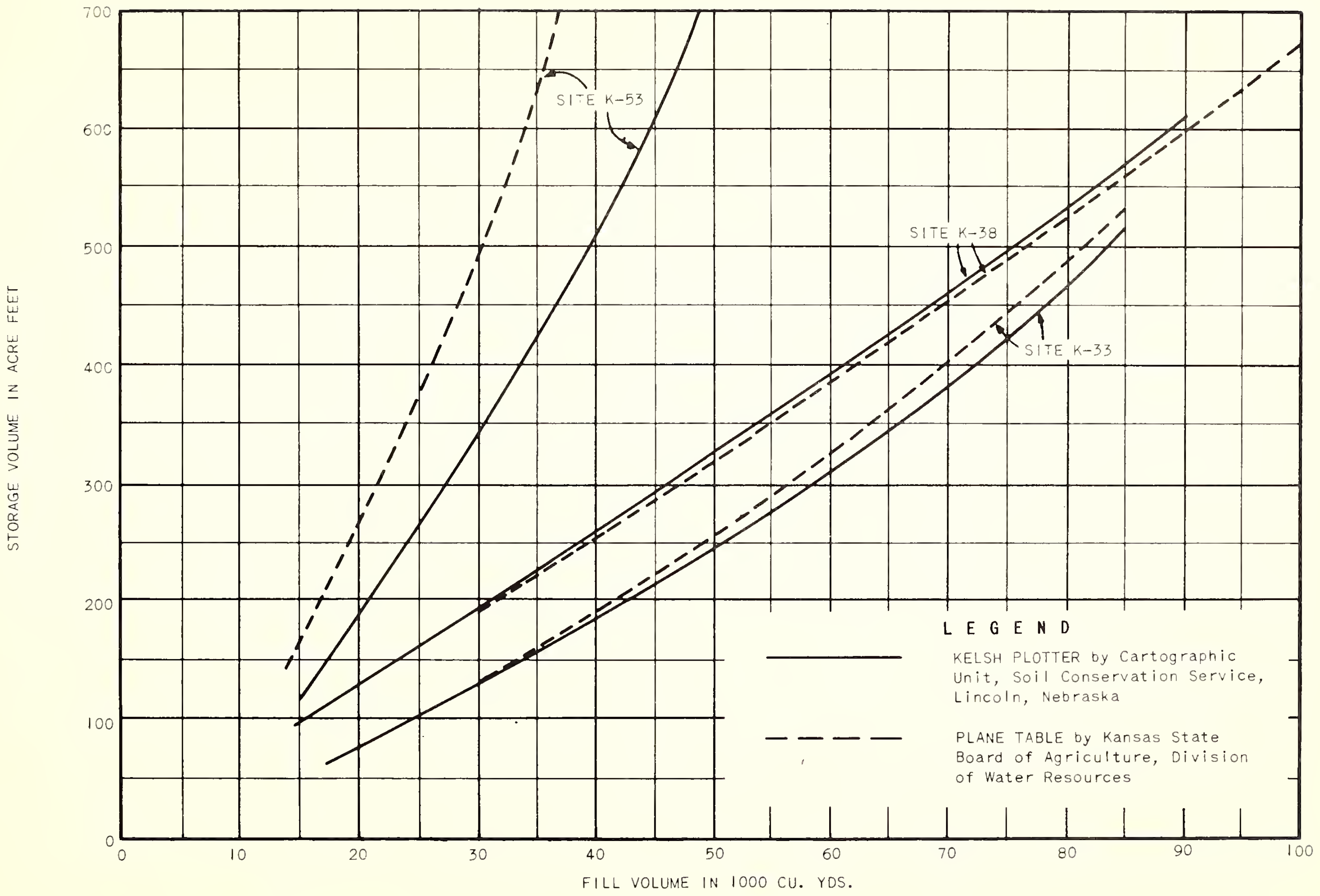


FIGURE NO. 54

COMPARISON OF MAPPING METHODS

UPPER VERDIGRIS RIVER WATERSHED

KANSAS

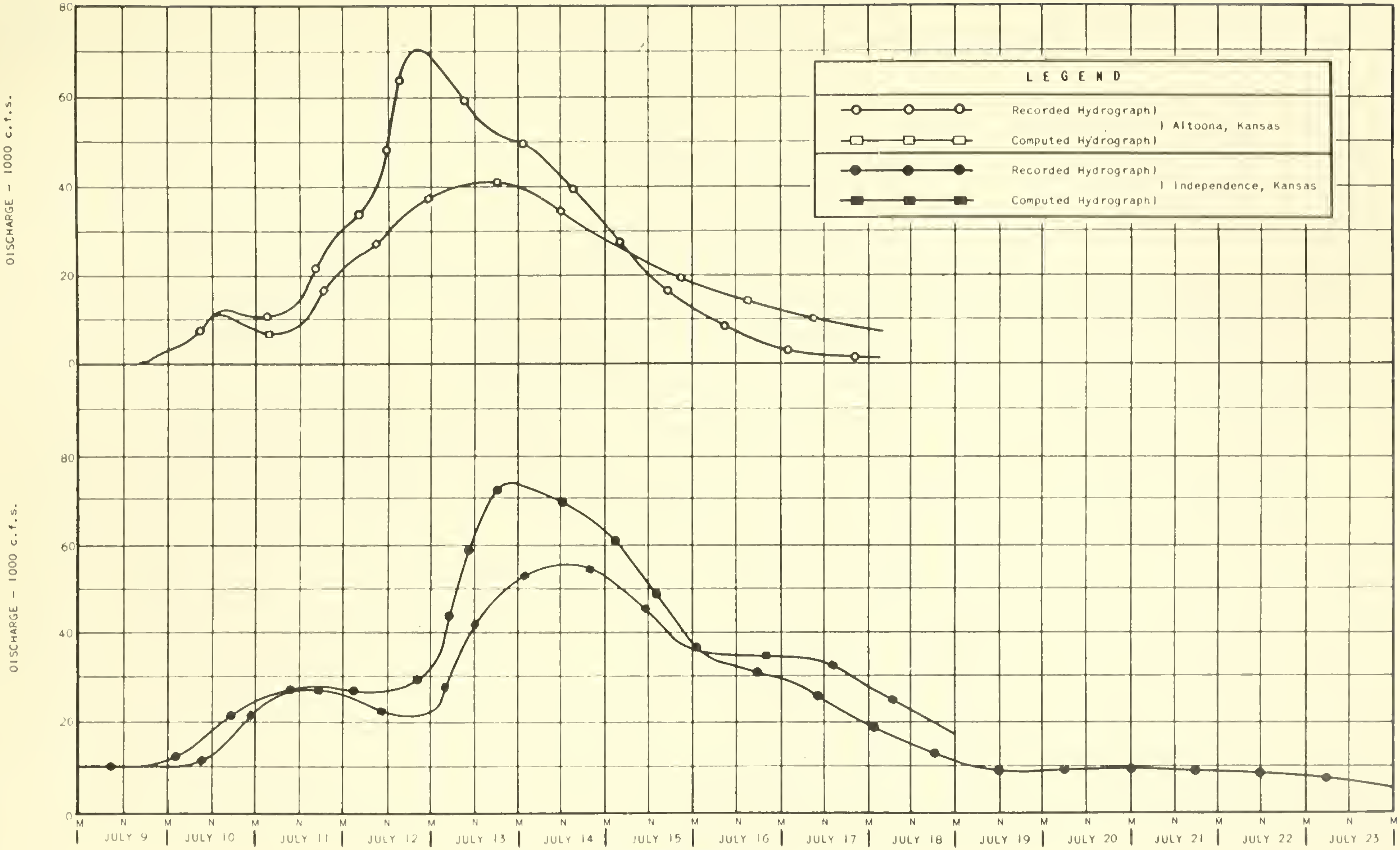


FIGURE NO 55
COMPARISON OF COMPUTED AND RECORDED HYDROGRAPHS
JULY, 1951 FLOOD AT
INDEPENDENCE AND ALTOONA, KANSAS GAGES

UPPER VERDIGRIS RIVER WATERSHED
KANSAS

REFERENCE: Prepared by USDA, Soil Conservation Service, Tulsa, Oklahoma, AWR Office